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Effect of Personnel Quality on the Performance of Patriot Air Defense System Operators

Bruce R. Orvis, Michael T. Childress, J. Michael Polich

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Prepared for the
United States Army

RAND

PREFACE

This report documents results of RAND Arroyo Center research on the linkage between the quality of enlisted personnel (in terms of aptitude score) and their ability to operate the Patriot air defense missile system. The purpose of the research was to improve the ability of the Army to set appropriate performance standards and to estimate the effects of personnel quality levels on Army operational performance. This study was one of several research efforts on soldier performance conducted by RAND and the U.S. Army Research Institute. The results should be of interest to manpower analysts in the Army, the Office of the Secretary of Defense, and the other services, as well as to policy analysts interested in the relationship between the aptitude of military enlisted personnel and their performance on combat-related jobs.

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SUMMARY

PURPOSE

The Patriot missile system, the most modern and automated of the Army's air defense artillery systems, protects U.S. and NATO assets from the high to medium altitude enemy air threat. This report describes a research study whose goal was to assess the performance of enlisted Patriot operators and to link that performance to the outcomes of simulated air battles. The Patriot study was one of several Army-sponsored research efforts aimed at analyzing the relationship between personnel quality and Army operational performance based on quantitative and objective performance tests.

THE PATRIOT SYSTEM

The basic building block of the Patriot system is a firing battery, or fire unit, which includes eight missile launchers, radar and communications equipment, and an Engagement Control Station (a mobile shelter containing communications facilities and computer consoles). During an air battle, the key engagement decisions in a Patriot battery are made by one officer and one enlisted person, who operate the Engagement Control Station. At battalion level (the next higher echelon), a comparable officer-enlisted pair operates a similar facility that controls the activities of three to six batteries.

At battery level, the enlisted person (military occupational specialty [MOS] 24T) helps the officer by playing the role of Tactical Control Assistant (TCA); at battalion level, he plays the role of Tactical Director Assistant (TDA). The research examined the effectiveness with which

- The TCA protects valuable assets, engages enemy aircraft, and assists in the protection of friendly aircraft as required for success during air battles.
- The TDA directs fire units to engage specific aircraft in order to protect assets and destroy enemy aircraft.

STUDY APPROACH

The study examined how differences in personnel quality and training background affect the execution of TCA and TDA functions and the outcomes of air battles. Virtually all of the Army's MOS 24T soldiers at skill levels 1 and 2 were tested, including students finishing Advanced Individual Training (AIT) and the members of Patriot units stationed in the United States and Europe. Approximately 100 students and over 200 unit personnel were tested during the study period, from December 1988 through June 1989.

The study used the Patriot Conduct of Fire Trainer (PCOFT), a computer-controlled, high-fidelity simulation facility containing operator consoles. The consoles can be operated independently to simulate autonomous fire unit operation or in a netted configuration to simulate fully interactive battalion operation.

Four 20-minute simulated air battles were developed especially for this test: an area defense scenario (aircraft attrition), a point defense scenario (asset defense), a mixed defense scenario (attrition and asset defense), and a battalion scenario. These scenarios included realistic wartime-related operations and events and provided a meaningful test of the performance of air defense missions for both AIT students and unit members. In addition, unit personnel completed a written test measuring their knowledge of proper tactical operating procedures, and all examinees completed a test on system initialization procedures.

RESULTS

The analysis concentrated on a number of key measures of effectiveness that primarily represented success in the missions of point defense and area defense. Additional supporting measures assessed compliance with tactics and doctrine, compliance with communications received, and knowledge of initialization procedures. We modeled the effects of various soldier characteristics (e.g., aptitude score, training history, and assignments to Patriot jobs) on performance.

The results provide considerable evidence that Armed Forces Qualification Test (AFQT) score has a direct and consistent effect on the outcomes of air battles, both in terms of knowledge assessed by written tests and in actual performance in simulations. The number of significant effects for AFQT score dominates the number of significant effects found for the other variables included in the model. In general, we found a 5 to 10 percent difference in performance by AFQT category.[1] For example, if a category IIIA soldier is used instead of a category IIIB, or a category II instead of a category IIIA, the anticipated increase in asset protection is on the order of 5 to 10 percent. Similarly, the anticipated increase in the number of hostile aircraft correctly engaged and in missile conservation is on the order of 5 to 10 percent. In short, then, soldiers with higher AFQT scores can be expected to suffer significantly less asset damage, destroy more hostile aircraft, and be more effective in missile conservation.

We also found substantial tradeoffs between AFQT and both operator experience and training days for many of the outcome measures: a one-level change in AFQT category equaled or surpassed the effect of a year of operator experience or of frequent training according to these data. These tradeoffs have significant readiness and cost implications in that higher quality soldiers, as measured by AFQT score, require less training and operator experience to perform as well as lower quality soldiers.

As expected, operator and unit experience also are very important variables. Next to AFQT, they are the factors that most consistently affect performance. It appears that soldiers learn several key tactical skills shortly after AIT, including the ability to decide whether and when to engage aircraft based on the nature and severity of the threat. In contrast, they appear to acquire technical and other tactical proficiencies more gradually, such as correct system setup and overall tactical knowledge. Finally, in a number of areas, we found that recent collective or sustainment training (consisting of practice using simulations such as the Troop Proficiency Trainer or the Live Air Trainer) had a significant effect. These results are notable because, together with the data on operator experience, they provide evidence linking training in units with success during air battles. The findings suggest the importance of unit training, along with personnel quality, in affecting mission performance.

[1]AFQT categories are defined by percentile scores normed on the U.S. youth population: category I, percentiles 93–99; category II, 65–92; category IIIA, 50–64; category IIIB, 31–49; category IV, 10–30. Category V persons, percentiles 1–9, are excluded by law from military service.

ACKNOWLEDGMENTS

This study was made possible by the support of the offices of the Commanding General and the Deputy Chief of Staff for Resource Management, U.S. Army Training and Doctrine Command. Particular thanks are due to General Maxwell Thurman, Major General Theodore Stroup, Lieutenant Colonel David Block (retired), and Major Robert Donoho for their encouragement and efforts. For design assistance and support, we are grateful to the U.S. Army Air Defense Artillery School at Fort Bliss and the 32nd U.S. Army Air Defense Command (AADCOM) in Germany, particularly Major General Donald Infante (retired), then Commanding General, USAADASCH; and Major General James Cercy, then Commanding General, 32nd AADCOM.

At Fort Bliss, we profited from the advice and assistance of Colonel William Miller (retired), then Director of Training and Doctrine; Colonel John McKinney (retired), then Director of the Patriot Department; Paul Gusset, Chief of the Courseware Development Division (CDD); and Tony Bush and Gail Levitt, who were responsible for the project office. Very special thanks are due to Andrew Washko, Chief of the Courseware Branch of the CDD, and to his staff for their continuing and invaluable support in the development of the air battle scenarios used in the study and in the conduct of the research. In the 32nd AADCOM, we are particularly grateful to Colonel Neal Delisanti, formerly G-3, and to Barry Miller of Sanders Associates for their counsel and support during the formative stages of this research; and to Sergeant First Class Merion McLemore, Staff Sergeant Howard Johnson, and Sergeant Martin Muse of the Patriot Conduct of Fire Trainer facility, whose advice, commitment, and persistence fundamentally contributed to the success of the study. At RAND, we owe a great deal to our coworkers from the Computer Information Science department: Janice Hartman, who conceived and carried out the arduous process of converting data from the Patriot system to our facilities and built the analysis variables from the resulting data files, and Jeffrey Garfinkle, who performed the crucial intermediate step of extracting relevant information from the raw data. Rebecca Mazel supervised and coordinated the automation of information obtained in the written tests and background questionnaire used in our research, Alvin Ludwig assisted in drafting portions of this report, Robert MacCoun and Beth Asch provided thoughtful reviews, Jeri O'Donnell performed helpful manuscript editing, and Kerrie Avery assisted in document preparation. Finally, we want to express our appreciation to Ellen Penington, our on-site expert consultant at Fort Bliss, who played a key role in the design and execution of the study.

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1. INTRODUCTION

BACKGROUND AND ISSUES

This document presents the results of research linking the quality of soldiers (as determined by aptitude score) to Army mission performance. It focuses on a specific weapon system—the Patriot air defense missile system—but the issue is much more general. The key problem is the relationship between enlistment standards and overall military capabilities. Historically, the Department of Defense (DoD) and the military services have sought to recruit the most talented individuals possible. A key criterion for enlistment is general aptitude, as measured by the Armed Forces Qualification Test (AFQT), which is part of the qualifying examination for admission to the military. A high AFQT score and possession of a high school diploma are the distinguishing characteristics of the "high quality" recruit most desired by the services. Recruiters naturally seek to maximize personnel quality by drawing primarily from the top half of the aptitude distribution.

Defense observers have often disagreed, however, about the appropriate "mix" of higher and lower quality enlistees. A key reason for disagreement has been the cost of recruiting a higher quality force. The high aptitude personnel sought by the services have attractive options upon graduating from high school, including various postsecondary education, employment, and military service possibilities. Thus, special incentives and other recruiting resources are required to attract these individuals into service. The problem has been especially acute for the Army, which recruits the largest number of new personnel each year.

Issues about the appropriate levels of recruiting resources and the levels of quality they support have been focal points of policy debate throughout the past two decades. When recruit quality has fallen, Congress has expressed concern, legislated minimum standards, and directed evaluations of new incentives to attract high quality people.[1] At the same time, policymakers in Congress and the Office of the Secretary of Defense have scrutinized recruiting budgets and asked for evidence linking personnel quality with job performance. In its report accompanying the FY 1988 military authorization bill, the House Appropriations Committee directed DoD to develop methods of linking the educational background and aptitude of recruits, both of which are associated with higher recruiting costs, to the ability of units to perform their *operational missions* (House of Representatives, 1988). In response to this requirement, the U.S. Army Training and Doctrine Command (TRADOC) sponsored the program of research that led to this study.

These concerns are likely to continue, and perhaps to intensify, as U.S. military missions and structures change in response to world political developments. If these changes lead to reductions in the size of the Army, as seems probable, resources devoted to recruiting and training new accessions will surely be examined more closely. Some people are likely to argue that in a smaller Army, maintaining a flow of high quality accessions will be less difficult, given current high levels of quality in the force and reduced demand. Others may argue that in a smaller Army, a higher proportion of the enlistees should be high quality. A smaller Army may need a greater proportion of high aptitude personnel if, for example, a higher concentration of sophisticated equipment is retained, soldiers are asked to perform a

[1]See, for example, RAND studies of experiments on educational benefits (Fernandez, 1982) and enlistment bonuses (Polich, Dertouzos, and Press, 1986).

wider variety of tasks, or there is less opportunity to practice tasks because of constraints on exercises (placing a premium on skill acquisition and retention).

Thus, even under changing circumstances, the defense community has a continuing need to understand the relationship between the quality of personnel and mission performance. The key questions concern the relationship of resources to yield, including both personnel resources (e.g., quality soldiers) and training resources. Ideally, these broad categories of inputs should be linked to measures of output based on objective, quantified assessments of individual and unit performance in wartime-related functions. This report seeks to address those issues in the case of air defense.[2]

PREVIOUS RESEARCH LINKING APTITUDE AND PERFORMANCE

Thus far, the literature has revealed only a modest amount of quantitative evidence relating aptitude, educational background, and training history to functions germane to unit combat capability. In the past, most analyses of personnel quality requirements have been based on the minimum aptitude levels that individual recruits need to pass initial skill training courses.[3] Recently, the Army's long-range job performance measurement project (called Project A) sought to provide better defined connections between various recruit characteristics and performance measures on specific critical tasks. Conducted by the Army Research Institute and three research organizations, this 7-year project was designed to improve selection and classification for entry level jobs in the U.S. Army. It developed new predictor and outcome measures and validated existing measures for 19 military occupational specialties (MOSs), including both paper-and-pencil for all 19 specialties and hands-on tests for nine of the specialties. However, like its predecessors, this effort emphasized individual and task performance, not performance in situations directly linked to a unit's wartime conditions and outcomes. (A comprehensive description is provided in Sackett, 1990.)

Within the air defense field specifically, a few studies have attempted to examine the connection between soldier aptitude and performance. For example, various studies have related different aptitude measures to each other and estimated their relationship to performance. Such studies have very frequently, although by no means universally, shown significant relationships. For example, Baldwin, Cliborn, and Foskett (1976) and Tubbs et al. (1980) found significant correlations between visual aircraft recognition (VACR) performance and Army Classification Battery (ACB) and AFQT scores, respectively; Deason (1981) found AFQT and "SelectABLE" math scores to be correlated with Chaparral gunners' "preparation for action"; Tubbs et al. (1982) found AFQT and Armed Services Vocational Aptitude Battery (ASVAB) scores to be positively correlated with scores on a skills-and-knowledge written test and a hands-on test for Hawk crewmen; Tubbs et al. (1984) found AFQT to be highly correlated with a skills-and-knowledge written test and with the sighting and identification skills of Stinger and Redeye crewmen; and Zamarripa (1987) found that the ASVAB Electronics score correlated with written scores for Pershing crewmen.

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[2]A related RAND study concerns performance of Army communications units (Winkler, Fernandez, and Polich, forthcoming). Studies in other branches have been carried out by the U.S. Army Research Institute (Graham, 1990 (A) and (B); Horne, 1990) and by TRADOC schools and centers (e.g., Schopper, Johnson, and Burley, 1990).

[3]TRADOC schools set minimum aptitude entry standards for their individual training courses, and training standards are established in various TRADOC-published Soldier's Manuals, ARTEP-MTPs (Army Training and Evaluation Programs and Mission Training Plans), and related publications.

The results of this previous research suggest but do not convincingly demonstrate that high quality soldiers outperform low quality soldiers in combat. Often, the aptitude-performance link is not systematically evaluated in these studies because it is a side issue, the primary focus being on such issues as evaluating the level of the soldiers' training on a particular weapon system (Tubbs et al., 1984; Zamarripa, 1987) or comparing different training methods (Baldwin, Cliborn, Foskett, 1976; Tubbs et al., 1980; Deason, 1981; Tubbs et al., 1982). Furthermore, the outcome measures used rarely assess performance directly translating to performance in combat, focusing instead on training success, written tests, or tasks representing only a small portion of the overall job. For example, in one of the few studies conducted expressly to examine the effect of aptitude on performance, LaRocque (1981) studied 2459 soldiers across 17 MOSs, comparing those who passed One Station Unit Training with those who failed. He found significant differences ($p<.0001$) between these two groups on ASVAB and Gates-MacGinitie (reading grade level) composite scales. Tubbs et al. (1982) used written tests and hands-on tasks as outcome measures. Deason (1981) had Redeye gunners "shoot" at targets in a Moving Target Simulator (MTS), but only compared AFQT with proficiency in operation, not with successful firing. Many of the studies also suffered from methodological or analytical difficulties that limit the confidence that can be placed in their aptitude results. For example, Baldwin, Cliborn, and Foskett (1976) and Tubbs et al. (1980) had few subjects for the types or number of tests conducted. Other studies performed multiple tests on the data without accounting for the multiple testing in probability estimates; still others did not test predictor variables simultaneously.

STUDY OVERVIEW

This report describes the results of a research effort whose primary goal was to rigorously assess the relationship between a soldier's aptitude and training and his performance in simulated combat. Specifically, we examined the proficiency of enlisted personnel who operate the Patriot air defense missile system and systematically related that proficiency to soldier characteristics, including AFQT score. The tasks performed by these soldiers, who are classified MOS 24T, are necessary to engage enemy aircraft and to protect friendly assets (such as airfields and storage facilities) during combat.

The Patriot is the Army's most advanced air defense system, designed to meet a variety of air threats in the 1990s and beyond. It is capable of simultaneously engaging multiple targets in a highly saturated air environment using advanced features in its radar, missile guidance, and computer and automation systems.[4] The basic building block of the Patriot system is a firing battery, or fire unit, which includes the following equipment, all truck mounted: eight missile launching stations, a radar set, an antenna mast group (communications equipment), an electric power plant, and an Engagement Control Station (ECS), which is a shelter containing communications facilities and computer consoles. During an air battle, the key engagement decisions in a Patriot battery are made by one officer (the Tactical Control Officer—TCO) and one enlisted person (the Tactical Control Assistant—

[4]Key features are the multifunction phased array radar, track-via-missile guidance, and computer-automated operations that process information and control missile launches. The radar set replaces several pieces of equipment used in earlier air defense systems, and the track-via-missile system allows guidance from the missile during the final engagement stage.

TCA) who, performing separate tasks, operate the ECS.[5] A similar officer-enlisted pair plays the main role at the next higher echelon, a Patriot battalion composed of three to six batteries.[6] This study evaluated the abilities of the two enlisted personnel and the effects of their performance on the outcomes of simulated air battles.

There were several reasons for choosing the performance of Patriot system operators for evaluation:

- To derive statistical estimates of the effects of personnel quality and experience on the outcomes of air battles.
- To provide results applicable to a modern system operating in a wartime-like environment.
- To provide test measures directly linked to air battle outcomes (asset damage and aircraft engagements).
- To assess the effects of personnel quality for both newly trained personnel and experienced unit members.

The primary work of MOS 24T personnel is to operate and provide unit maintenance for the Patriot missile system. This research tested the principal operational functions:

- *TCA* (fire unit level): The ability to protect valuable assets, engage enemy aircraft, and assist in the protection of friendly aircraft during air battles.
- *Tactical Director Assistant—TDA* (battalion level): The ability to direct fire units to engage specific aircraft in order to protect assets and destroy enemy aircraft.

In addition, this evaluation assessed operator knowledge of proper system initialization procedures and tactics.

The performance of TCA and TDA functions was evaluated using the Patriot Conduct of Fire Trainer (PCOFT), a high-fidelity, computer-driven training facility that represents the principal functions of the actual tactical equipment. The PCOFT contains operator consoles that show incoming aircraft (scripted according to a preestablished scenario), safe passage corridors, defended assets, and other airspace and ground features relevant to the fire unit's or battalion's mission. During a simulated air battle, the operators track and engage aircraft, and the computer records all switch actions. As we will describe in detail, the records maintained by the simulator provide a wide range of effectiveness measures that were used to evaluate the performance of Patriot operators in a realistic, wartime-like environment. Maintenance functions were not tested in this study because they are fundamentally different from operator functions and could not be tested with the same rigor given the current state of maintenance simulators.

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[5]The station's crew also includes a communications operator in MOS 31M, but that person is not directly involved in air battle operations.

[6]During the study period, a battalion consisted of three batteries. Eventually, six batteries will be fielded per battalion. The addition of three batteries could complicate the job of the 24T operator at the battalion level.

REPORT OUTLINE

The remainder of this report presents the research approach, design, and results. Section 2 describes the approach taken in the research, including a description of the simulator from which the performance measures were drawn, the scope of the tasks tested, and the personnel examined. Section 3 presents the specific research design and procedures for testing. It also includes a detailed description of all outcome measures and principal predictor variables. Section 4 contains regression results and selected statistics for the primary outcome measures; Section 5 provides similar information for a variety of supporting measures. The conclusions are presented in Section 6. Finally, Appendix A provides supplementary tables containing all regression coefficients, scores for the study variables, and additional statistics; and Appendix B presents an illustrative cost-benefit analysis.

2. RESEARCH APPROACH

The research used an existing high-fidelity simulation system (the PCOFT) and associated written tests of tactical operations and initialization procedures to examine the proficiency with which air defense soldiers perform the Patriot TCA and TDA missions. The examinees were tested on their ability to protect valuable assets, engage enemy aircraft, and assist in the protection of friendly aircraft, both at the fire unit and the battalion level of operations.

FUNCTION AND SPECIALTY TESTED

The U.S. Army Air Defense Artillery protects U.S. and allied assets from enemy air attack and has the further mission of causing maximum attrition of enemy aircraft. The current air defense inventory includes the Redeye, Stinger, Vulcan, Chaparral, Hawk, and Patriot systems.[1] The Patriot is the most modern and automated of these systems. Together with the Hawk, the Patriot provides protection from the high to medium altitude threat. It is capable of simultaneously tracking large numbers of aircraft and of engaging and destroying them at varying ranges. At the time of this study, U.S. Army Patriot battalions were located at Fort Bliss, Texas, and in the Federal Republic of Germany. Subsequently, Patriot units were deployed to Saudi Arabia and Israel, where they played a well-known role in defense against missiles during the Persian Gulf War.

A Patriot firing battery, or fire unit, includes a fire control section and eight launchers. Each launching station loads four missiles. The heart of the battery is the fire control section, which includes an Engagement Control Station (ECS), antenna mast group, radar set, and electric power plant. The ECS, which is a mobile shelter mounted on an M-814 vehicle, is manned by three crew members: one 24T enlisted member and one 14E officer, who together control the air battle, and one 31M enlisted communications operator (who is not directly involved in the air battle). The ECS is the only fire unit equipment manned during tactical operations. It is capable of operating in *autonomous* mode, i.e., as a stand-alone facility using its own radar and making its own firing decisions; and in *centralized* mode, i.e., in combination with the ECSs of up to five other batteries to form a battalion under the command of the Information and Coordination Central (ICC). The ICC is similar to the ECS in general appearance and features but monitors a wider sector of operations and directs the activity of subordinate ECSs via voice and digital data links when the battalion is operating in centralized mode.

Patriot enlisted personnel fall into one of three classifications: MOS 16T, Patriot Missile Crew Member; MOS 24T, Patriot Operator and System Mechanic; and MOS 24T with Additional Skill Identifier T5, Intermediate Maintenance Specialist. MOS 16T personnel are responsible for marching and setup duties for the Patriot equipment. MOS 24T personnel are responsible for operation of the ECS and the ICC and for unit level maintenance.

[1]The Redeye and Stinger are shoulder-fired low altitude missile weapons; the Vulcan, a truck-mounted antiaircraft gun; the Chapparal, a truck-mounted low altitude missile weapon; and the Hawk and Patriot, multiunit, medium to high altitude missile weapons.

This study concentrated on the operator duties of 24T personnel. Their key functions are

- *TCA* (fire unit level). The TCA engages aircraft as they approach defended assets (such as airfields or depots) and launches missiles against other enemy aircraft when fulfilling an attrition mission, all in accordance with tactical standing operating procedures and instructions from higher echelons. The TCA also assists the TCO in identifying aircraft, carries out changes in airspace control methods (such as electronic identification codes or safe air space zones), initializes the equipment before a battle, and carries out emergency maintenance duties.
- *TDA* (battalion level). The TDA keeps track of aircraft across areas defended by the battalion's subordinate fire units and directs fire units to engage aircraft in accordance with tactical procedures. He assists the Tactical Director in management of the battalion's assets during the battle and performs other functions similar to those carried out by the TCA.

MOS 24T is awarded after successful completion of 37 weeks of Advanced Individual Training (AIT) at the U.S. Army Air Defense Artillery School, Fort Bliss, Texas. During the 37-week period, both ECS and ICC operation training are provided.[2] This training concentrates on system initialization procedures and the asset defense mission. After graduation, MOS 24T personnel receive further (unit) training in these areas. In addition, they receive training in the aircraft attrition mission and in air battle tactics. Tactics include such topics as airspace control methods and rules of engagement.[3] For graduating AIT students forming new units at Fort Bliss, these topics are covered locally in collective training before deployment of the unit overseas (e.g., to U.S. Army Europe). For soldiers shipping directly to Germany, these topics are covered upon arrival at the U.S. Army's European air defense element, the 32nd Army Air Defense Command (AADCOM). Overseas, 24T personnel receive additional training covering local procedures and priorities.

TESTING ENVIRONMENT

This study used the PCOFT, which replicates operation of the ECS and ICC. PCOFTs are located at the Air Defense Artillery School at Fort Bliss and at the 32nd AADCOM headquarters at Darmstadt, Germany.

Description of PCOFT

The PCOFT is a computer-controlled, high-fidelity simulation facility consisting of eight operator consoles. The consoles can be operated independently to simulate autonomous ECS (fire unit) operations or in a netted configuration to simulate fully interactive battalion

[2]Students also receive extensive training in unit maintenance.

[3]Airspace control methods apply to the nonelectronic (passive) means of helping to ensure that hostile aircraft are engaged and that friendly aircraft are not. They include factors such as safe passage corridors (volumes of air space in which it is safe to fly), weapon control volumes (volumes of airspace within which certain engagement rules apply), and speed or altitude restrictions. The rules of engagement specify the tactical operating procedures, i.e., what is to be engaged and what is not, based on the airspace control criteria, electronic identification results, and other factors.

operations. The PCOFT duplicates the TCA and TDA consoles in the tactical equipment, which consist of a display screen showing aircraft, airspace, and ground features, and various panels of switches. The features displayed on the screen are affected by operator actions in the same way they would be in a real ECS or ICC. The PCOFT is driven by a master computer, which, with a real-time interface, tabulates the individual actions taken by the operators and the air battle outcomes resulting from those actions. These data are recorded on a disk that can be read later for analysis. On behalf of RAND, the PCOFT software contractor, Sanders Associates, Inc., developed additional, special software for tabulating new measures of individual performance and air battle results. The PCOFT contains a central system manager console from which the air battle scenarios are run, examinees' actions can be monitored, and the system is controlled.

RAND and the Air Defense Artillery School designed a test of the TCA functions for the ECS and the TDA functions for the ICC. This test allowed us to examine how differences in personnel quality, job experience, and training affect the execution of these functions and the outcomes of air battles.

Rationale for Using PCOFT

We selected the PCOFT as the testing medium for five reasons. First, it provides realistic simulation of TCA and TDA duties, for which the actions and outcomes can be measured objectively and precisely by computer. Second, the results of a given simulation can be translated directly into air battle outcomes. Third, the computer records can provide many details on the process of the battle, including the specific procedural steps that may contribute to desirable or undesirable results. Fourth, unit and battalion level operations can be measured without using tactical equipment—a considerable advantage given the small number of ECSs and ICCs in existence and the great demand for them. Fifth, the PCOFT permits testing in the same controlled environment for all soldiers, both at Fort Bliss and in the 32nd AADCOM.

3. STUDY DESIGN

We designed the study to assess the MOS 24T personnel's ability to perform critical wartime duties. The entire testing procedure was administered and supervised by experienced air defense and RAND personnel. This section describes the testing components, the examinees and scheduling, the specific testing procedures, and the performance measures and analysis.

TESTING COMPONENTS

The major testing components used in the study were the Patriot console, the air battle simulations, and the written tests.

Patriot Console

Figure 1 illustrates a simplified version of the console display used by MOS 24Ts in the ECS. This display has a number of important features that the TCA must interpret and relate to the tactics prescribed for his particular mission. For example, the display shown has three safe passage corridors marked C01, C02, and C03. These corridors are used by the Patriot's software in its attempts to identify friendly and hostile aircraft via an algorithm that assigns points based on electronic interrogation, aircraft location and heading, and other factors The algorithm assigns positive points to aircraft flying in a safe passage corridor (normally friendlies), thus reducing the likelihood that they will be engaged.

The aircraft on the display that have been identified as friends are indicated by circles; those identified as hostile aircraft are indicated by diamonds. The numbers next to each aircraft are flight identifiers, which are referenced in the engagement queue at the bottom of the chart (to be described shortly). At the top of the chart is a line labeled R01 on the left and P01 on the right, indicating restricted and prohibited volumes. When an aircraft is inbound and passes that line, it receives negative points in the algorithm, increasing its chances of being classified as hostile—unless, of course, it is in one of the safe passage corridors.

At the lowest point of the triangle are two squares marked A and B. They represent assets: *A* represents the ECS itself, and *B* represents an asset being defended by the ECS. At the very bottom of the chart is a simplification of the engagement queue. The operator uses the queue to assist in fighting the air battle. For instance, note that the hostile aircraft (indicated by diamonds) are displayed in the engagement queue: flights (shown as TGTNO) 11, 7, 12, and 9. In the first row, there is a 2B in the threat (THRT) column. That means that flight 11 is close enough to asset B to be evaluated as a threat to it, and that the asset threat code of B is 2, which is the second highest priority level.

The next column is labeled TLL, meaning "time to last launch." This entry shows the remaining time in which the aircraft can be engaged before it damages the particular asset against which it is being evaluated. For example, there are 15 sec left in which to engage flight 11 before it will be too close to B to be destroyed before it overflies B (given its current

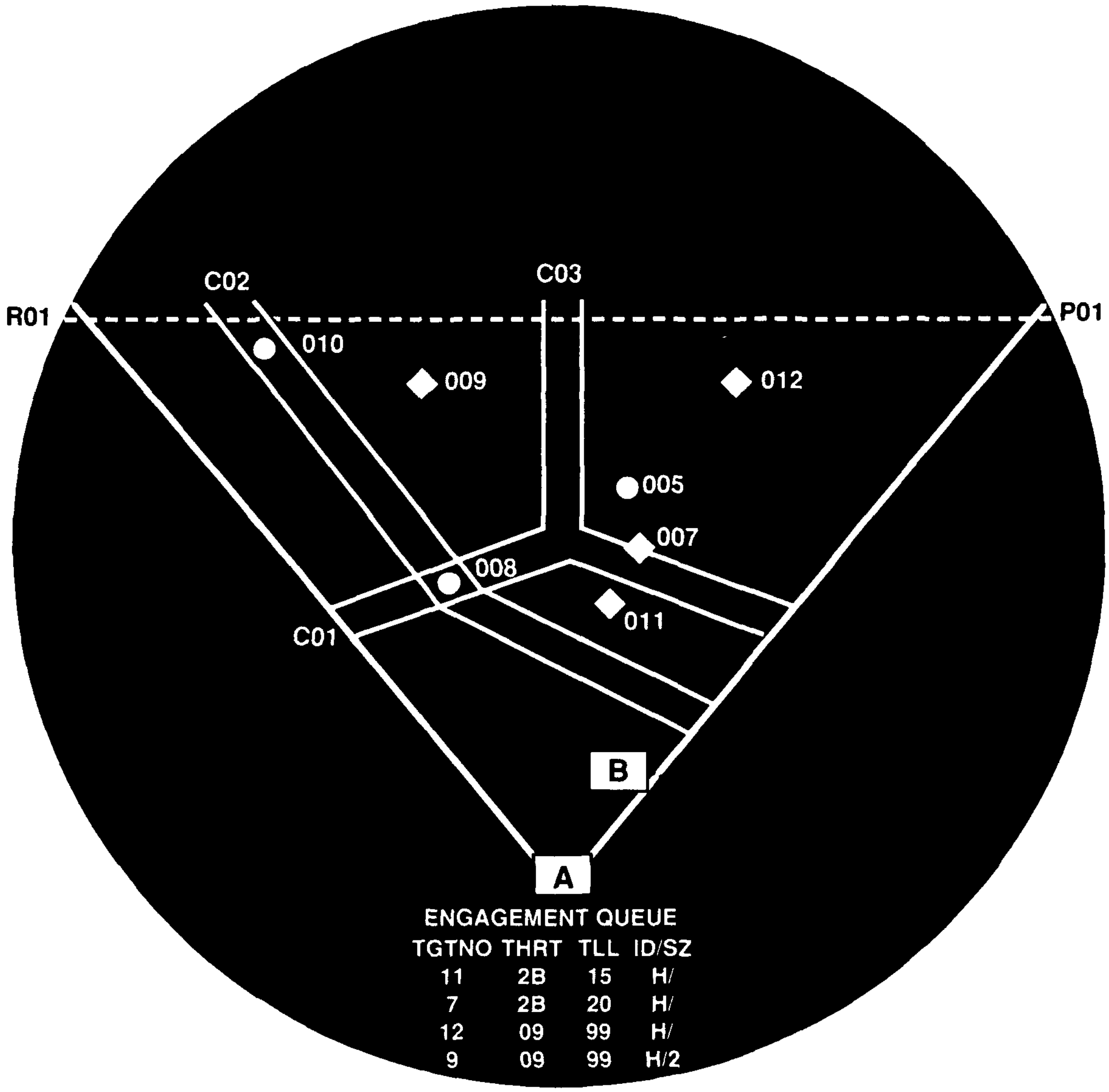

Fig. 1—Illustrative Example of Patriot Console Display

heading and speed). Flight 7 is somewhat farther away, but still close enough to be evaluated against asset B with a TLL of 20 sec. Thus, the operator has an additional 5 sec to engage flight 7. The two bottom flights, 12 and 9, are far enough from both assets that their asset threat codes are designated simply as 9, meaning a general threat, and their TLL values have not yet begun to count down.

Finally, the last column (ID/SZ) shows an H (*for hostile*) for all of the aircraft. It also shows that each has a flight size of 1, except for flight 9, whose 2 after the slash indicates that two aircraft in close proximity are being tracked with that flight number. Such multiple-aircraft targets may require a different firing method for effective engagement (e.g., two missiles fired instead of one).

Even though the display in Figure 1 is simplified, it shows enough detail to exemplify the complexity of the Patriot operator's job. In the heat of battle, the operator must recognize the information displayed on the screen and in the engagement queue, interpret it in light of the operating procedures (tactics) in effect at that time, resolve ambiguities of identification and priority, and destroy the appropriate hostile aircraft. Launches and firing patterns appropriate under one set of tactical instructions may be inappropriate under alternative rules of engagement. For example, the tactical instructions may prescribe engagements based on such factors as threat to particular types of assets, target aircraft heading, and current identification (e.g., hostile). One implication is that even though Patriot is highly automated, fighting the air battle is by no means an automatic process. The enlisted soldier seated in the ECS must continuously interpret and monitor the information on the console and relate it to the applicable tactics to decide which engagements are appropriate.

Simulated Air Battles

Four 20-min air battles were simulated. The first three covered battery level operations; the fourth, battalion level. The particular features of each scenario and the specific tactical instructions to be followed were developed especially for this test by subject matter experts at Fort Bliss and the 32nd AADCOM in consultation with RAND. The scenarios and tactics were designed to be realistic with respect to required wartime operations and events. They were also designed to provide a meaningful test of the performance of air defense missions by both recent AIT graduates and experienced unit members. The flight events scripted into the scenarios represent the challenges that can be expected in wartime. They included features such as masking; jamming; varying aircraft headings, formations, speeds, and altitudes; air-to-surface missiles; and aircraft with varying degrees of identification equipment problems.[1]

Area Defense Scenario. The area defense scenario typified TCA operations required during wartime in forward areas. The air defense mission is to destroy the maximum number of enemy aircraft (consistent with prescribed tactical procedures and rules of engagement, including requirements for self-defense). The scenario began in the centralized mode. During this period, the examinee received from the ICC specific engagement and tactical instructions that had to be properly executed. Subsequently, he was instructed to change to autonomous operation of the ECS. While in the autonomous mode, he was solely responsible for his actions. As was true for all scenarios, the examinee received information concerning his mission and the tactics to be followed at the beginning of the scenario. To provide a standardized (and realistic) protocol, the examinee was instructed to use the automatic aircraft identification mode and to assume that the identifications were valid.[2]

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[1]For example, aircraft may enter a Patriot unit's area on various headings (some threatening defended assets, some not), they may turn or change altitude unexpectedly, they may fly within or outside various corridors and designated airspace volumes, and they may mask themselves by flying behind terrain features such as mountains. The RAND scenarios were specifically designed to represent these and other complex aircraft behavior patterns that are realistically expected in wartime and that pose challenges to missile system operators, who must keep track of numerous events occurring simultaneously and interpret them in relation to prescribed rules of engagement.

[2]*Automatic* in this context means that the computer identifies an aircraft as friendly, hostile, or unknown based on calculations from various input evaluation criteria.

Point Defense Scenario. The point defense scenario typified TCA operations required during wartime in rear areas. The air defense mission is to defend the assets assigned to the examinee's fire unit, such as air bases, built-up areas, storage facilities, and other high priority locations. The scenario was run in the autonomous mode of operation. Halfway through the scenario, the examinee was informed that his TCO (the officer with whom he was fighting the air battle) had died and that he thus had to also assume the officer's function of protecting friendly aircraft (for which he had been trained). After assuming this added function, he received two instructions to carry out changes in the procedures for identifying hostile and friendly aircraft. The first told him to change the current IFF (Identify Friend or Foe) codes to an alternative set. The second told him that certain features of the airspace control methods had been compromised, and that he thus needed to manually identify aircraft to ensure their proper identification as hostile or friendly.[3]

Mixed Defense Scenario. The mixed defense scenario simulated a wartime situation in which the examinee's primary mission was to destroy enemy aircraft and his secondary mission was to defend an air base assigned to the fire unit. Again, the missions had to be carried out in a manner consistent with the tactical instructions provided to the examinee just before commencement of the air battle. The scenario was run in the autonomous mode of operation.

Battalion Scenario. The battalion scenario typified ICC operations required during wartime. The examinee's role was to assign individual enemy aircraft to the fire units under the control of the ICC and order their engagement. The order included the method of fire, i.e., the number of missiles to be fired and the timing of the launches.[4] The orders had to be issued in accordance with the battalion's mission and the specified tactical instructions. In this scenario, the mission was asset defense.

Written Tests

In addition to being tested on their performance in fighting simulated air battles, the examinees were required to complete written tests. Unit members completed one test measuring their knowledge of proper tactical operating procedures and a second test measuring their knowledge of system initialization procedures at the unit and battalion levels.[5] Soldiers just concluding AIT completed only the initialization test, since tactics are taught primarily during unit training. Each test consisted of 25 multiple-choice questions. The tactical test questions were drawn from official sets of questions used to test unit members' tactical qualification for TCA duties. The initialization test was drawn from items used to assess comprehension of initialization procedures during AIT.

The examinees also completed a background questionnaire that collected information on their education, training history, unit assignments, history of job responsibilities, and air de-

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[3]In this situation, the operator must disregard the identifications generated by the computer for aircraft within the compromised area, instead exercising his knowledge of airspace control methods to make identifications himself according to doctrine and the tactical procedures prescribed for the scenario.

[4]The appropriate number of missiles depends on the number of aircraft in a confined airspace and the degree of threat posed by the aircraft, among other things. The more missiles fired, the greater the probability of destroying the targets; but it is important to conserve the supply of missiles, especially for self-defense.

[5]Initialization consists of entering into the computer parameters that govern air battle operations, such as terrain features, airspace control methods, and codes for electronic identification of friendly and hostile aircraft.

fense experience. This information was used to supplement official records concerning their performance on the ASVAB.

EXAMINEES AND SCHEDULING

We scheduled for testing all MOS 24T soldiers at skill levels 1 and 2, including personnel concluding AIT and the members of Patriot units stationed both in the continental U.S. (Fort Bliss) and Europe.[6] The test excluded skill levels 3 to 5 (senior personnel) because our primary concern was the quality of *recruits*.[7] The distribution of MOS 24T personnel worldwide for the study period is provided in Table 1. The AFQT category distribution for these soldiers is shown in Table 2.[8] As an indication of the aptitude requirement for MOS 24T (the dimension this study addresses), note that 75 percent of MOS 24T personnel fall into categories I through IIIA, as compared to approximately 50 percent of the U.S. youth population. The percentage of category I through IIIA personnel at skill levels 1 and 2 is about 10 points higher than at skill levels 3 to 5, indicative of the greater recruiting success and demand for skilled personnel experienced by the military during the past few years.

AIT classes graduating during the study period were included in the test. AIT students were tested after they had received all applicable training instruction, near the end of their AIT course. Unit members were scheduled so as to accommodate unit training activities and exercises.

Table 1

Worldwide Distribution of MOS 24T Personnel by Skill Level and Pay Grade

	Skill Level 1		Skill Level 2	Skill Level 3	Skill Level 4	Skill Level 5	
Command[a]	E1–E3	E4	E5	E6	E7	E8–E9	Total
USAREUR	18	115	34	74	42	15	298
FORSCOM	58	35	29	35	23	4	184
TRADOC	7	29	24	87	57	14	218
AMC	0	15	6	9	7	3	40
Others	0	1	0	1	0	0	2
Total	83	195	93	206	129	36	742

[a]The full names of the listed commands are U.S. Army Europe, Forces Command, Training and Doctrine Command, and Army Materiel Command, respectively.

[6]Soldiers in the junior grades (E1–E4) are at skill level 1; they typically have 1 to 4 years of service. Soldiers at pay grade E5 are at skill level 2 and normally in their second term of enlistment. In isolated instances, individuals located at a CONUS station other than Fort Bliss, Texas, in transition to a U.S. Army Europe unit, performing jobs not related to Patriot, or on leave were excused from testing.

[7]Twenty soldiers undergoing transition training into MOS 24T were tested.

[8]AFQT categories are defined by percentile scores normed on the U.S. youth population: category I, percentiles 93–99; category II, 65–92; category IIIA, 50–64; category IIIB, 31–49; category IV, 10–30. Category V persons, percentiles 1–9, are excluded by law from military service.

Table 2

AFQT Category Distribution of MOS 24T

AFQT Category	AFQT Range (Percentiles)	Percentage of Total		
		Skill Levels 1–2	Skill Levels 3–5	All Skill Levels
I	93–99	6.2	9.8	7.6
II	65–92	47.0	37.9	43.5
IIIA	50–64	24.7	20.6	23.1
IIIB	31–49	19.3	23.7	21.0
IV	10–30	2.8	8.0	4.8

The final phases of software testing and procedural pretesting were completed during September, October, and November 1988. Testing began in December 1988 at Fort Bliss, Texas, and in January 1989 in Darmstadt, Germany. At Fort Bliss, we tested AIT students graduating in MOS 24T and MOS 24T personnel, skill levels 1 and 2, in school support and Forces Command units during the period December 1988 through June 1989. In Germany, unit members were rotated into the PCOFT facility at Darmstadt in groups of approximately four persons per day, making it possible to test one battalion's 24T personnel, skill levels 1 and 2, in 2 weeks. Testing was completed in Germany by April 1989. In total, we examined 218 unit personnel and 97 AIT students.[9]

Of the 315 examinees, 126 were stationed in units in Germany and 189 (92 unit members and 97 AIT or Transition Training students) were stationed at Fort Bliss. All students were tested just prior to graduation.[10] The distribution of the examinees by location is displayed in Table 3.

Table 4 shows the AFQT category and pay grade distributions of the examinees. The first column shows the AFQT and pay grade distributions for all persons. The results are then separated for unit members versus AIT students. The primary AFQT difference between the unit members and AIT students is the smaller percentage of category IIIB personnel among the students, reflecting the Army's higher recruiting standards in recent years. The unit results are fairly comparable for members stationed overseas and at Fort Bliss. For

Table 3

Number of Persons Tested by Location

Location	Number Tested	Percentage of Sample
Germany	126	40.0
Fort Bliss		
Unit member	92	29.2
AIT student	97	30.8

[9]These numbers are somewhat lower than those shown in Table 1 because, as noted, in certain instances persons located at a CONUS station other than Fort Bliss, in transition to a U.S. Army Europe unit, performing jobs not related to Patriot, or on leave were excused from testing. Also, some personnel were prevented from being tested at their scheduled time because of computer problems and could not be rescheduled.

[10]For 21 of the 315 examinees, we could not obtain matching AFQT information from the Defense Manpower Data Center. *The distribution of the missing AFQT data was as follows: five in Germany; nine in Fort Bliss units, and seven in AIT.*

Table 4

Characteristics of Personnel Tested (in percent)

Characteristic	Total	Units: Germany	Units: Fort Bliss	AIT
AFQT category				
I	4.7	3.3	5.0	6.3
II	47.7	48.3	42.5	51.9
IIIA	23.3	20.0	25.0	26.6
IIIB	20.4	24.2	22.5	12.7
IV	3.9	4.2	5.0	2.5
Pay grade				
E1	1.0	0.0	0.0	3.7
E2	16.0	0.8	1.1	55.6
E3	14.2	6.4	9.0	32.1
E4	43.4	60.8	50.6	8.6
E5	25.4	32.0	39.3	0.0

Note: These numbers do not include 20 individuals who were self-reported as undergoing transition training. In addition, there were 21 examinees (five of whom were in transition training) whose AFQT scores could not be determined.

pay grade, the unit members naturally consist of more senior personnel. Nine-tenths of the AIT students were drawn from pay grades E3 and below, whereas nine-tenths of the unit members were drawn from grades E4 and E5. The overall distributions of both AFQT category and pay grade among the examinees closely correspond to those reported earlier in Tables 1 and 2 for the MOS 24T population at skill levels 1 and 2 (pay grades E1 through E5).

SPECIFIC PROCEDURES

Two people were tested simultaneously. Each pair of examinees initially was given a short briefing describing the purpose and procedures of the test and assuring them of the confidentiality of the results. They were then asked to complete a short background questionnaire.

To facilitate testing and to prevent possible cooperation between the pair of examinees, the timing of the individual components of the test was staggered. At no point did the two examinees simultaneously complete the same written test or fight the same air battle. The complete testing procedure required 3 hr per pair of examinees.

One of the examinees began by taking the simulated air battle portion of the test. After concluding all of the simulated air battles, he was asked to complete the written initialization test and, if a unit member, the written tactical operations test. The second examinee completed the written test(s) before beginning the first simulated air battle. The order of the air battles was the same for all examinees: area defense scenario, mixed defense scenario, point defense scenario, and battalion (ICC) scenario. The order was based on providing continuity and an increasing level of difficulty.[11] Just before the beginning of each scenario, the exam-

[11]The practice effects that result from ordering the scenarios according to increasing level of difficulty may have facilitated performance in the later air battles to a limited extent for persons who had not recently performed

inee was provided with written instructions concerning his mission and the applicable air defense conditions and tactics. The scenarios were written to allow the participants 1 min to set up their consoles before the first engageable aircraft appeared.

PERFORMANCE MEASURES AND ANALYSIS

The PCOFT facility computer tabulated all air battle switch action and outcome records automatically. RAND developed additional software to analyze these records for different purposes, for example, to identify hostile versus friendly aircraft engagements and to assess adherence to tactical instructions.

Measures of Effectiveness

Table 5 shows the measures of effectiveness that were used to evaluate the performance of the examinees. The measures are divided into primary and supporting measures. The primary measures reflect the direct outcomes of the air battles, such as asset damage and specific aircraft engagements. The supporting measures reflect actions and knowledge that contribute to success on the primary measures. Table 6 lists the specific test factors that were evaluated and relates them to the applicable measures of effectiveness. Each factor was evaluated separately for each scenario and examinee. The factors cover the broad range of responsibilities a 24T would be required to perform in a hostile wartime environment. Below is a more detailed description of each factor and how it was evaluated. The factors are presented according to whether they relate to the primary or supporting measures of effectiveness.

Factors Related to Primary Measures of Effectiveness. The factors related to the primary measures of effectiveness were as follows.

Number of hits to each asset by priority of asset. The goal of the asset defense mission is to protect friendly assets from enemy air strikes. Naturally, the ECS itself must also be protected. In our study, the mixed defense scenario had one defended asset, and the point defense and battalion scenarios had two defended assets. Moreover, these assets had an underlying priority that the examinee should adhere to in fighting the air battle. For exam-

Table 5

Measures of Effectiveness for Patriot Operator Performance

Primary measures
A. Asset defense
B. Hostile aircraft killed in accordance with tactics
C. Missile conservation
Supporting measures
D. Tactical proficiency
E. Technical proficiency

as TCAs or TDAs. In our opinion, and by design, this situation is realistic because such persons would be given an opportunity to practice before participating in a real battle if at all possible.

Table 6

Specific Test Factors Related to Measures of Effectiveness

Factor	Measure of Effectiveness[a]				
	Primary			Supporting	
	A	B	C	D	E
Scenario Tests (Area, Mixed, Point, Battalion)					
Number of hits to each asset by priority of asset	X				
Number of hits to ECS	X				
Number of hostile aircraft engaged (IAW[b] tactics and not IAW tactics)		X	X		
Number of friendlies engaged			X		
Missiles used			X		
Tactical correctness of engagements					
In netted configuration				X	
Specified asset threat code targets				X	
Safe passage corridor				X	
Time to last launch				X	
Position of aircraft and flight path at launch				X	
Specified slow speed targets				X	
Fire patterns IAW tactics and not IAW tactics (number of shoot-look-shoot, ripple, salvo by type of target—e.g., raid size, threat code level)				X	
Success in manual aircraft identification procedures				X	
Console setup					X
Execution of engagement, cease fire, and hold fire commands					X
Execution of IFF code change					X
Written Tests					
Score on written initialization test adapted from program of instruction					X
Score on 32nd AADCOM-adapted TCA qualification test (units only)				X	

[a]See Table 5 for a description of measures A through E.

[b]In accordance with.

ple, the first priority in the scenarios was given to defending the ECS (i.e., self-defense), and additional priorities were given to the assets per se. As a result, for a given air battle scenario, we were able to determine both the total number of hits sustained from hostile aircraft and the pattern of damage sustained according to the underlying asset prioritization.

Number of hits to ECS. Whether performing an area (attrition) or point (asset) defense mission, the soldier must engage in self-defense. As noted above, we could determine how well examinees defended themselves by identifying the number of hits the ECS sustained.

Number of hostile aircraft engaged. We tabulated the total number of hostile aircraft engaged during each scenario. Moreover, we did this in terms of tactical correctness so that we had two measures. One was simply a straight count of the number of hostile aircraft killed and the other was a count of the number of aircraft that were killed correctly according to tactics. The criteria used to evaluate tactical correctness are discussed below (see Tactical Correctness of Engagements). If the examinee committed any of the specified errors, the hostile aircraft was deemed not to have been killed in accordance with tactics. One might argue that the way in which a hostile aircraft is killed is of little significance. However, this is not the case. Among other reasons, tactical procedures are established to minimize the potential engagement of friendly aircraft, to ensure that missiles are not wasted due to multiple engagements of the same aircraft, and, in some instances, to avoid the escalation of conflict. These are extremely important considerations, and, for this reason, we focus on tactically correct kills.

Number of friendly aircraft engaged. With certain limited exceptions, friendly aircraft were scripted to comply with tactical procedures concerning the use of passive (flight pattern) and active (electronic) identification means. Under such conditions, friendly aircraft are unlikely to be engaged by the Patriot system, and our count of such instances clearly reflects this fact. However, we did include several instances of electronic identification malfunctions or problems that increased the possibility of engaging a friendly aircraft. Furthermore, a portion of the point defense scenario required manual identification of aircraft, which also increased the likelihood of engaging friendly aircraft.

Total missiles used. The examinees were given 32 missiles in the area and mixed defense scenarios, 64 in the point defense scenario, and 96 in the battalion scenario. We constructed a measure of missile conservation that reflects the ratio of missiles used per hostile aircraft killed in accordance with tactics.

Factors Related to Supporting Measures of Effectiveness. The factors related to the supporting measures of effectiveness reflect actions and knowledge that underlie success in the air defense mission. Thus, we specially designed our test to permit the assessment of performance on these individual factors. Moreover, to properly simulate the outcomes of actual air battles, we ensured that poor performance on these factors resulted in potential degradation of mission success at the broader level—for example, in greater damage to defended assets or to the ECS. These factors were as follows.

Tactical correctness of engagements. During an actual air battle, operators must comply with various tactical procedures while engaging hostile aircraft. The tactics specified in our test closely resembled current operating procedures. They were modified to some extent to protect classified information, and, for similar reasons, some of the detail concerning the tactical criteria is intentionally omitted from the ensuing discussion. In somewhat general terms, each engagement was evaluated according to the following criteria, which were developed for the purpose of the test:[12]

- *Netted error*. This is a tactical error committed by engaging an aircraft without authorization while in the centralized mode of operation.
- *Asset threat code error*. Each hostile aircraft is automatically assigned an asset threat code depending on its flight behavior and proximity to assets. Examinees were instructed to engage only those aircraft that exhibited an asset threat code designation within a certain range of values, which depended on the mission.
- *Safe passage corridor error*. In our test, no aircraft were engageable while flying in a valid safe passage corridor. If the examinee violated this directive, the killed aircraft was considered not to have been killed in accordance with tactics.

[12]It was not always possible to commit all of these errors on each engagement. For instance, a netted error could only be committed in the first 8 min of the area defense scenario, during centralized operation. Moreover, only a few aircraft flew at a slow speed and only a few enemy aircraft flew in safe passage corridors.

- *TLL error*. The Patriot system automatically calculates the time to last launch for the operator, which is the number of seconds remaining before the hostile aircraft is too close to the threatened asset to be destroyed before it reaches that asset. Examinees were directed not to engage an aircraft unless its TLL value was below a certain level in order to conserve missiles and maximize the probability of kill.
- *Crossing and outbound error*. Aircraft flying in a crossing or outbound direction were authorized for engagement only if they posed a specified threat and a certain number of missiles were still available for firing.
- *Slow speed error*. No slow speed target was to be engaged unless it directly threatened the fire unit and the TLL was below a certain level.
- *Method of fire error*. Specific method of fire criteria were to be followed during engagements; they were a function of flight size (number of enemy aircraft) and the nature of the threat. Specifically, the *salvo* method fired two missiles in rapid succession, the *ripple* method fired two missiles but with a longer intervening period, and the *shoot-look-shoot* method fired a single missile. Shoot-look-shoot was the normal method of fire.

Success in manual identification procedures. The examinees were instructed to manually evaluate all aircraft flying in a particular, compromised safe passage corridor during the final 5 min of the point defense scenario. This evaluation required them to call up certain information onto the console screen so they could determine whether the aircraft would be considered hostile if it were not credited with positive points for being inside the compromised corridor. From this point forward, 15 aircraft flew in the corridor, five of which were actually hostile but appeared not to be. The examinee was evaluated on whether the five hostile aircraft were correctly identified.

Console setup. In all scenarios except the battalion scenario, the administrator checked the examinee's console at approximately 90 sec and 2 min into the air battle to determine if he had set up the console and activated the launching stations in accordance with instructions. The instructions provided information concerning the console and required the examinee to conserve four missiles for self-defense by deferring activation of one of the launching stations.[13] If the administrator found the console setup to be incorrect at the 90-sec mark, she advised the examinee to check the console. If the setup still was incorrect at 2 min, the administrator informed the examinee how to correct any remaining problems. Thus, the two checks reflected an unaided measure and an aided measure, respectively.

Execution of engagement, cease fire, and hold fire commands. Examinees were ordered to engage specific aircraft in the area defense and battalion scenarios. Accordingly, they were evaluated on whether they complied with these orders. In addition, a cease fire and a hold fire command were given at the beginning of the battalion scenario. These commands required distinct switch actions, but, in general terms, their intent was to prevent the engagement of the specified aircraft.

Execution of IFF code change. Twelve minutes into the point defense scenario, a message was transmitted to the examinee indicating that the IFF code had been compromised. The enlistee then had to change the code by calling up a particular tab onto the con-

[13]We were unable to meaningfully evaluate examinee performance in setting up the battalion console because battalion operations were unfamiliar to and proved difficult for most of the examinees.

sole screen and entering the newly specified code information. We evaluated whether this procedure was performed correctly and in a timely fashion.

Written tests. As previously mentioned, all examinees completed an initialization test, and all unit members completed a test assessing knowledge of tactical standing operating procedures. The tests were drawn from official items. The measure assessed was simply the percentage of correct answers. To more meaningfully detect variations in individual performance, pretest results were used to select items of intermediate difficulty, yielding an expected score of approximately 50 percent correct.

Summary Outcome Measures

One of the desires expressed by the Air Defense Artillery School was that the results be summarized according to their implications for battlefield survival, tactical proficiency, and technical proficiency. In consultation with school personnel, we developed a plan to combine the individual output measures captured during the simulated air battles into these three broad measures as follows:

1. *Battlefield survival.* This is an overall measure of the examinee's performance on asset defense, hostile aircraft killed in accordance with tactics, and missile conservation.[14] It has an obvious and direct connection with battlefield survival.
2. *Tactical proficiency.* This measure reflects how well the examinee complied during the air battles with the individual tactical criteria that underlie the tactical correctness of engagements. These criteria include method of fire, time to last launch, asset threat code, and netted errors, and performance on manual identification procedures.[15]
3. *Technical proficiency.* This is an overall measure of how well the examinee set up the console (including launchers), complied with engagement commands, executed the IFF code bank change, and scored on the written initialization test.

Based on the advice of the air defense experts, the individual measures combined into each summary measure were weighted equally.[16] Our analysis supports the viability and reliability of the summary measures. The Cronbach's alpha coefficients for the overall summary measures computed across the three battery scenarios are 0.80 for battlefield survival, 0.61 for tactical proficiency, and 0.74 for technical proficiency. (See Appendix A.)

[14]The missile conservation measure is discussed in detail later. It concerns the number of missiles the examinee required to destroy one hostile aircraft in a tactically correct manner. The remaining primary factor, number of friendlies engaged, was excluded because its rare occurrence argued against weighting it equally with the three pervasive factors identified above.

[15]The tactical measures were adjusted so that the percentage used is really an error rate per engagement rather than just a straight error rate. This adjustment was done on method of fire, time to last launch, and asset threat code in order not to penalize operators with more engagements. We decided not to include the safe passage corridor, slow speed target, and flight path (outbound or crossing) measures because there were limited opportunities for these errors, and the written tactics test was excluded because it was taken only by unit members.

[16]The panel recommended that the individual factors within a summary area be given equal weight because their relative values would vary depending on the particular features of an air battle or mission. To accomplish this end, the individual measures composing the overall summary score were converted to Z-scores and added together. To facilitate the comparison of results across the three summary categories (explained in more detail in Section 4), the resulting score also was standardized so that its mean was 0 and its standard deviation was 1. The resulting summary measures were computed for each scenario individually as well as for the three battery level scenarios together.

Principal Predictor Variables

We modeled the effects of various soldier characteristics on these multiple performance measures using multivariate regression analysis. Before arriving at the final model specification, alternative predictor variables and models were explored. For example, in addition to AFQT score (a general aptitude measure), we examined other composites of the aptitude scales contained in the ASVAB that assess aptitude in specific areas, such as electronics and motor maintenance. We also looked at the examinee's educational level and years of education; training background; general experience factors, such as time in service, current grade, time since AIT, time in MOS, location of service, and type of prior unit (e.g., Patriot or other air defense units); and specific job history variables, such as extent and recentness of previous service as a TCA, TDA, and maintainer.

We were guided by the need to distinguish (a) AIT students from unit members in order to assess whether potential aptitude effects attenuated with experience and (b) persons stationed overseas from those at Fort Bliss in order to control for possible differences in knowledge, procedures, and practice. We were also guided by the policy relevance of AFQT score as compared with other composites, the need to control for and identify the effects of operator experience and recent training, and the desirability of minimizing the number of predictor variables. Our review led us to select the following six predictor variables as our model:

1. *AFQT percentile score.*
2. *Operator months.* This is the total number of months the examinee had served as TCA or TDA since graduation from AIT/Transition Training as a 24T (coded as "0" for AIT students).[17]
3. *Unit membership.* This is a dichotomous variable to distinguish between AIT students and graduate unit members.[18]
4. *Training days.* This is a self-reported measure of the number of sustainment or collective training days a unit member had received during the last 6 months on the Live Air Trainer (LAT), Tactical Proficiency Trainer (TPT), or PCOFT.[19]
5. *Location.* This dichotomous variable indicating station at Fort Bliss (AIT students or unit members) or in Germany (unit members) was included to deal with possible differences in operating procedures.
6. *TDA experience.* This variable was included in the model only for analyses that pertained directly to outcomes in the battalion scenario. It is a dichotomous variable to differentiate between those who were *currently* acting as TDAs and those who were not.

The additional aptitude measures, background factors (such as education and time in service), and job history variables were excluded because they did not improve prediction of performance.

[17]TCA experience typically dominates this measure, since the mean value is 7.4 months compared to only 1.6 months for TDA experience.

[18]We also checked to see if certain units performed consistently better or worse than others. Only a few, isolated effects were found. As a result, the dichotomous variable sufficed to control for unit designation.

[19]Embedded training on the tactical equipment accounted for nearly all of the training reported: LAT training, which uses images of actual air traffic in simulated air battles, averaged 9.0 days during the last 6 months; TPT training, which uses scripted air traffic patterns, averaged 7.6 days. PCOFT training averaged only 0.5 days.

The aptitude data were obtained from official records, including enlistment testing files maintained by the Defense Manpower Data Center and Army records from the Enlisted Master File. Location of assignment and unit membership status also were determined from these records. The experience and training variables were defined using self-reported questionnaire data from the examinees. Together, these factors should provide an accurate assessment of the effects of personnel quality on performance because they control for significant individual differences in experience or training. Although some of the predictor variables clearly are related to others (e.g., one must be a unit member to be stationed in Germany), there is no evidence of multicollinearity problems. The highest correlation between AFQT percentile score and the other predictors was .04 (for operator months); among the remaining predictor variables, intercorrelations ranged from .21 (training days with location in Germany) to .54 (unit member status with location in Germany). Moreover, among these non-AFQT variables, when we omitted one predictor at a time and used the remaining variables to predict its value, the multiple R-squares ranged from only .27 to .35. (See Appendix A for additional information on correlations and R-squares among the predictor and outcome variables.)

4. RESULTS FOR PRIMARY MEASURES

This study assessed air battle performance in key areas of capability. The primary outcome measures included asset defense (e.g., number of hits on all assets and damage by individual asset priority), hostile aircraft killed in accordance with tactics, and missile conservation. In this section, we discuss our analytical approach and present regression results for the primary measures. We begin with a brief comparison of performance among unit members and graduating AIT students.

UNIT MEMBER VERSUS STUDENT SCORES

The test incorporated realistic and challenging scenarios. This fact is confirmed by the feedback we received from the test participants. In the early development of the study, one of the concerns was that realistic scenarios might be so difficult that the AIT students would not be able to handle them, which might lead to wide differences in performance between AIT students and unit members. Alternatively, there was concern that if the scenarios were simplified for the AIT students, they would be too easy for the unit members and perhaps unrealistic. These concerns about the feasibility of designing a common test proved unfounded.

Table 7 shows some simple data for the primary outcome measures. These data clearly indicate that AIT students and unit members performed comparably on the key measures in the test. There are some differences between the groups due to acquired experience and training, but clearly the test was meaningful both for the AIT students and the unit members.

The first group of data in Table 7 shows summary statistics on the total number of hits taken against defended assets, including the ECS. For each of the scenarios, three numbers are presented: the mean, or average, number of hits taken, and the minimum and maximum number of hits taken by any test participant.[1] The results are presented separately for AIT students and unit members. Among AIT students, the average number of hits taken ranged from 1.5 in the area defense scenario to 15.1 in the battalion scenario. Note that the number of hits taken increases steadily across the four scenarios, reflecting the increasing level of difficulty we scripted into them.[2] Indeed, most of the study participants found the battalion scenario extremely difficult and challenging. For each scenario, there was a substantial

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[1]Occasionally, we experienced problems with outliers on some of the output measures. Outliers pose a potential problem, since the resulting distributional skew can bias the results. This problem can be addressed by transforming the variables. For example, a log transformation normally ameliorates this problem. Unfortunately, transformations make interpretation of the results more difficult. After verifying that the basic pattern of the results did not change, we decided instead to adopt a *four standard deviation rule*. In a normal distribution, 99.994 percent of the cases are located within four standard deviations of the mean value. We believe this to be sufficiently inclusive. Thus, if a particular observation deviated from the mean for a given variable by more than four standard deviations, we eliminated it. This was not a common problem, and resulted in the elimination of two or fewer cases (typically, none) per analysis.

[2]One should *not* conclude from these results that 24Ts are inherently less capable of performing a point defense mission than an area defense mission, for example. To reiterate, differences in these results reflect in large measure the particular characteristics we built into each of the scenarios. For example, there were five hits scripted in the software for the area defense scenario, whereas there were 13 scripted in the point defense scenario. We discuss below how we dealt with this difference so we could compare results across scenarios.

Table 7

Mean, Minimum, and Maximum Scores for Primary Outcomes[a]

Measure	AIT Students Mean	AIT Students Min	AIT Students Max	Unit Members Mean	Unit Members Min	Unit Members Max
Asset Damage						
Area defense scenario	1.5	0	5	1.3	0	5
Mixed defense scenario	4.8	1	9	4.2	0	9
Point defense scenario	6.4	2	12	6.1	2	11
Battalion scenario	15.1	5	23	14.9	5	23
Hostile Aircraft Killed IAW[b] Tactics						
Area defense scenario	7.1	1	13	8.8	1	16
Mixed defense scenario	15.6	4	24	17.8	3	25
Point defense scenario	21.1	5	34	23.8	7	37
Battalion scenario	10.0	0	18	11.5	0	21
Ratio of Missiles Used per Tactically Correct Kill						
Area defense scenario	3.9	1.3	16.0	3.1	1.3	13.0
Mixed defense scenario	2.0	1.3	3.9	1.8	1.2	4.0
Point defense scenario	2.4	1.3	6.1	2.1	1.4	6.1
Battalion scenario	6.8	2.2	32.5	5.9	1.9	32.0

Quartile Values at the 25th, 50th, and 75th Percentiles

	Asset Damage 25th	Asset Damage 50th	Asset Damage 75th	Hostiles Killed 25th	Hostiles Killed 50th	Hostiles Killed 75th	Missile Ratio 25th	Missile Ratio 50th	Missile Ratio 75th
Area	1	1	2	6	8	11	1.9	2.5	3.6
Mixed	3	4	6	15	18	20	1.5	1.7	2.0
Point	5	6	7.5	19	23	28	1.7	2.0	2.4
Battalion	12	15	18	7	12	15	2.9	3.6	6.6

[a]Reading down the table, the standard deviations for the means are 1.0, 1.8, 2.0, 4.4, 2.8, 3.8, 5.9, 4.7, 2.6, 0.5, 0.9, and 6.7 for the AIT students, and 0.9, 1.8, 2.0, 3.8, 3.4, 3.7, 6.7, 4.7, 2.1, 0.5, 0.7, and 5.6 for the unit members. The number of cases varies slightly, but is generally about 90 for the AIT student measures and 211 for the unit member measures.

[b]In accordance with.

range of scores from the minimum to the maximum, whereas both the mean score and the range of scores were quite similar for the AIT students and the unit members. In other words, most of the variation in asset damage for these scenarios was across individuals, rather than between AIT students and unit members. This finding confirms the meaningful and challenging nature of the test for both groups.

There are similar results in the second group of data, which shows the number of hostile aircraft killed in accordance with tactics. Again, there is a wide range of values among individuals for each scenario, and again the performance of AIT students is fairly similar to that of the unit members. In each case, the maximum score achieved by the unit members is slightly higher than that achieved by the AIT students. This result is not surprising, given that the bulk of tactical procedures is taught in the units.

Finally, the means, minimums, and maximums for the ratio of missiles fired per tactically correct kill (the third group of data) are consistent with those discussed above. On this conservation measure, which penalizes the examinee for improper missile usage, AIT students had slightly larger mean ratios than did unit members, indicating that AIT students typically fired more missiles than did unit members per tactically correct kill, i.e., did not conserve missiles as well. This result follows from that discussed in the preceding paragraph if the number of missiles fired is held constant, because the AIT students had a somewhat smaller number of tactically correct kills.[3] In the main, however, the results once again indicate that most of the variation in performance occurred across individuals, not between AIT students and unit members.

ANALYTICAL APPROACH

As previously mentioned, we used multivariate models to assess performance across a broad range of outcome measures, including both individual measures (e.g., damage to particular assets) and more broadly based, summary indices. The models assessed performance based on an array of personnel factors, focusing on aptitude. For example, a typical analysis at the more broadly based, summary level might examine the total asset damage sustained in a particular air battle as a function of the examinee's AFQT percentile score, the number of months experience he had as an operator of an ECS or ICC, whether he was currently in a unit or was simply completing initial training, whether he was stationed in CONUS or in Germany, and the number of training days he had received in the unit on the TPT, LAT, or PCOFT during the previous 6 months.

The simplest way to investigate the effects of our predictor variables on the outcome measures is to analyze the raw scores obtained on these measures. We conducted such analyses; all results are shown in Appendix A, and the results for the primary outcomes are summarized later in this discussion, in Figures 9, 10, and 11. Such analyses reveal, for example, the impact of AFQT score on the number of hostile aircraft killed. The problem with this simple approach is that most of the outcomes are characterized by unique scales reflecting characteristics idiosyncratic to each scenario. For example, the number of asset hits scripted into the software was 5, 10, 13, and 23 for the four scenarios, respectively. Moreover, the number of hits scripted against specific assets within each scenario also varied. So, too, did the number of hostile aircraft that could be engaged and the total missiles available for engagements (32, 32, 64, and 96). Each scenario also possessed distinguishing attributes that tested particular technical or tactical skills and influenced the level of difficulty. As a result, virtually every outcome measure has a different average value and distribution of scores. Since the means and standard deviations are different for the various outcomes, the resulting regression coefficients based on raw scores are not directly comparable within or across scenarios.

To facilitate comparison of the influence of the predictor variables on different outcomes, both within and between scenarios, we standardized our dependent variables. By transforming all outcomes to Z-scores, with the same mean (0) and standard deviation (1), we

[3]The maximum ratio values for both the area defense and battalion scenarios are quite large. These values are not indicative of how the typical examinee performed. The frequency distribution presented at the bottom of Table 7 reveals that the vast majority of examinees experienced scores well below the maximum. Moreover, the scores were further below the maximum for these two measures than for the other measures in the table. For example, in the area defense scenario, 75 percent of the examinees demonstrated a missile-to-hostile-kill ratio of 3.6 or less, which is well below the maximum values of 16 and 13. Similarly, in the battalion scenario, 75 percent of the examinees ordered 6.6 or fewer missiles to be fired per kill, which is well below the maximum value of 32. The wider range of variation in performance for these scenarios most probably can be attributed to the need for an adjustment period among some individuals (the area defense scenario was the first tested, and the battalion scenario was the first nonbattery scenario) and to the lack of familiarity with battalion operations shown by many examinees.

were able to compare the effects of the predictor variables across these different measures using a common yardstick.[4] For example, we could compare the effect of AFQT score (or any other predictor variable) on a soldier's ability to kill hostile aircraft in different types of missions, and we could also compare the effect of AFQT score on kills to that on defending assets. The standardized outcomes were analyzed using ordinary least squares (OLS) regression. The coefficients obtained in those analyses are shown in Appendix A.

REGRESSION RESULTS

Although the use of standardized outcome measures provides a common yardstick with which to compare the effects of given predictor variables across outcomes and scenarios, it still is not completely satisfying for the purpose of presentation. This drawback is attributable to the fact that standardized outcomes can take on an infinite range of values that indicate only the direction and (number of) standard deviations of the difference between the given score and the mean score for the particular outcome. In contrast, the probability values associated with the standardized outcome scores represent a measure with more intuitive appeal. They range from 0 to 1, or, in terms of percentages, from 0 to 100 with an average value of 50. These values are derived directly from the Z-scores, using a cumulative standard normal distribution. For example, a Z-score of 0 equals a probability of 50 percent. Conceptually, the result represents the *percentile ranking* of the Z-score, and it indicates the extent to which the soldier performed well or poorly relative to other 24T soldiers on the given outcome measure.[5]

As just discussed, standardization of the outcome scores (and use of the resulting probability values) facilitates comprehension and generalization of the study results. Clarity also

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[4]The formula for a Z-score is: (raw score for person i [X_i] − mean of X) / standard deviation of X. The Z distribution is also referred to as the *standard normal distribution*. This distribution is centered around a mean of 0, has a standard deviation of 1, and is symmetric. Therefore, a Z-score is the number of standard deviations of the score away from its mean.

[5]The predicted standardized outcome value for a soldier with a particular AFQT score and given characteristics on the other predictor variables is calculated as follows, using the regression coefficients provided in Appendix A:

$$Z = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5$$

where

Z = predicted Z-score on outcome measure
a = intercept
b_1X_1 = AFQT regression coefficient × AFQT percentile score
b_2X_2 = OPERMON coefficient × months of operator experience
b_3X_3 = UNITMEM coefficient × unit membership score (1 or 0)
b_4X_4 = *LOCATION coefficient × overseas location score (1 or 0)*
b_5X_5 = TRAINDAY coefficient × number of training days

The resulting Z-score is entered into the cumulative standard normal distribution to determine the associated percentage score.

All standardized results are reported with higher numbers indicating better performance than lower numbers. In cases for which a high Z-score reflected poor performance, the Z-score was multiplied by −1. For example, the standardized asset damage scores were multiplied by −1 to produce measures of asset defense. Note that the predicted Z-score can be reconverted to a raw score by using the Z-score formula to solve for Y. This formula is simply Y = (Z × stddev) + mean. The standard deviation and mean values in this formula refer to the raw distribution and are provided in Appendix A. For outcomes with reversed polarity, the formula is Y = (−Z × stddev) + mean. These outcomes include asset damage, friendly kills, netted errors, and tactical errors per engagement. For missiles used per hostile killed in accordance with tactics, the reciprocal of the raw result was used.

can be facilitated by summarizing the results for the continuous predictor variables in terms of more meaningful units for comparison. Rather than simply reporting the change in outcome associated with an increase of one AFQT percentile point, a month of operator experience, and a day of training (the units used in the regression analyses), we summarized the results for these predictors in terms of an increase of one AFQT category, a year of operator experience, and a one-day-in-ten training schedule. This summarization helped us examine the tradeoffs among aptitude, experience, and training and their implications for readiness.

Specifically, the first column of Tables 8 through 11 shows the predicted change in outcome score resulting from an increase in AFQT score of 21 percentile points ("one category") measured from the midpoint of category IIIA. The 21-point figure represents the average difference between the midpoints of category IIIB versus IIIA and category IIIA versus categories I and II combined, which together account for nearly all MOS 24T soldiers. The other columns show the effects of a year of experience as an operator at an ECS or ICC (from 0 to 12 months), unit membership (i.e., whether the person belongs to a unit as compared to being an AIT student), being stationed in Germany as compared to at Fort Bliss, and collective or sustainment training (using, primarily, the TPT or LAT) at a rate of 1 day per 10-day period during the preceding 6 months (from 0 to 18 days).[6] Double asterisks indicate that the factor was statistically significant in predicting outcome in the indicated scenario (i.e., p-value < .05), and single asterisks indicate that the factor was marginally significant (i.e., p-value between .05 and .10).

Of the factors evaluated, AFQT score showed significant effects most consistently. Given that virtually all the MOS 24T soldiers were high school graduates, the AFQT results translate directly to quality effects. Each of the other variables also showed some significant effects, particularly operator experience and unit membership. Together with the simulation training results, the effects for these variables provide evidence of a direct link between unit training and performance in air battles.

Each of the regression summary tables is followed by one or more figures. The purpose of the figures is to illustrate graphically the predicted variation in performance as one moves across the midpoint of each AFQT category while holding the other predictor variables in the regression model constant at their average values. In other words, the figures show how the performance of 24T soldiers who are identical on operator, unit, overseas, and training status is predicted to vary with AFQT score. The figures illustrate results for the mixed and point defense scenarios, which represent different battery level missions carried out autonomously and include the defense of multiple assets.

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[6]The mean score for each predictor variable lies in the middle of the indicated range. Note that the predicted changes in outcome would be somewhat smaller if measured from the extremes of the predictor variable distribution (such as 2 to 3 years of operator experience) because the (constant) Z-score change estimated in the regression translates to decreasing percentage point changes at these extremes.

We want to remind the reader that the purpose of the regression tables is to summarize and facilitate comparison of the results in meaningful units. The continuous variables included in the summarized regressions were AFQT percentile score, months of operator experience, and number of days of training in the preceding 6 months.

Asset Defense

Table 8 summarizes the regression results for asset defense. Each row shows the effect of the predictor variables on asset defense for a particular scenario.[7] The entries represent a soldier's predicted improvement in defending all assigned assets, including the ECS(s), on a scale that ranges from 0 to 100 and has an average value of 50 among the examinees (representing the vast majority of MOS 24T soldiers).

We were particularly interested in the extent to which each of the factors showed a statistically significant effect on asset defense and in the comparative magnitude of the factors' effects. For example, looking across the first row, one finds a significant increase in predicted ECS defense in the area defense scenario for an increase of one AFQT category: 7.2 points. In other words, even if their other characteristics were identical, replacing a category IIIA soldier with a category I or II soldier would result in a significant improvement in asset defense. A similar improvement can be expected if a category IIIB soldier is replaced with a category IIIA. The results for other factors generally were in the expected direction, but none of them approached statistical significance.

There was a greater number of significant effects in both the mixed and point defense scenarios. For example, in the mixed defense scenario, the expected increase in asset defense by AFQT category was again significant at 10.3 points; in the point defense scenario, it was significant at 9.5 points. We also found that operator experience had a significant effect: about an 8.4 point increase in expected asset defense for a year of operator experience. At the far right of the table, note the significant effect of training days in the point defense scenario, equaling a 5.6 point increase in anticipated asset defense, assuming 1 training day every 10 days. In the battalion scenario, the only statistically significant effect was that soldiers in units stationed in Germany did better in defending their assets than did unit members stationed in CONUS. The marginally significant negative effect for unit membership is

Table 8

Summary of Regression Results for Asset Defense (predicted change in asset defense score on scale of 0 to 100)

	Factor				
Scenario	AFQT Category	Operator Year	Unit Member	Germany Station	Simulation Training Day Each Ten Days
Area defense (ZDAMAGE1)	7.2**	3.2	5.6	–0.1	2.8
Mixed defense (ZDAMAGE2)	10.3**	8.4**	2.4	4.8	1.6
Point defense (ZDAMAGE3)	9.5**	8.4**	–7.2	4.8	5.6**
Battalion (ZDAMAGE4)	2.4	3.6	–10.7*	15.8**	–0.4

NOTE: Single asterisk signifies a marginally significant factor ($p < .10$); double asterisk signifies a statistically significant factor ($p < .05$).

[7]To assist the reader interested in cross-referencing the basic regression results used to derive Table 8 and all similar tables,the names used in Appendix A for the outcome variables are given in parentheses in the tables.

helpful in interpreting this result. The interpretation is that soldiers stationed in Germany (all of whom are unit members, thus getting the sum of the two coefficients) outperformed AIT students (who get neither coefficient) by about 5 points, and that the students outperformed the unit members at Fort Bliss (who simply get the unit member coefficient) by about 11 points. As mentioned earlier, our results indicate that most of the soldiers had quite a bit of difficulty with the battalion scenario, probably because, relative to the other scenarios, it was more complex and they had less opportunity to practice. The foregoing pattern could indicate that after receiving asset defense training at the battalion level in the PCOFT during AIT, most soldiers did not have a meaningful opportunity for sustainment or collective training in the TDA role until they shipped overseas.

What are the implications of these results? Looking down the columns of Table 8, one can see that AFQT category shows significant predicted effects on success in asset defense most consistently, followed by operator experience. Moreover, in each battery level scenario, the numbers indicate that an AFQT category is worth as much as or more than a year of operator experience or frequent training in terms of preventing asset damage. The results have readiness and cost implications, because they suggest that higher quality soldiers, as measured by AFQT score, require less training and operator experience to perform at the same level as lower quality soldiers.[8] The training results must be interpreted with caution, however, because the measure relies on self-reports of training over the preceding 6 months. It is likely that a more precise measure might reveal a greater effect, although it seems unlikely that it would surpass that of AFQT. Nonetheless, even this rough measure provides some evidence of the efficacy of simulation training and, when considered together with the operator experience effects, of unit training procedures.

Asset Defense by AFQT Category

Thus far, we have looked at the asset defense results in terms of the predicted change in performance associated with each predictor variable in the regression model. Here, we focus on the predicted effects of AFQT score, the main variable of interest, by visually comparing the expected performance of the members of different categories (holding the other factors constant at their mean values). Figure 2 illustrates this approach; it shows predicted performance in asset defense for the mixed and point defense scenarios on the 0 to 100 scale for categories I through IV, evaluated at the midpoint of each category. The issue is the extent of predicted variation around the average score of 50 as one moves across AFQT categories. The numbers of individuals tested in categories I and IV were small, whereas the numbers in categories II, IIIA, and IIIB were much larger. Thus, the results for categories I and IV must

[8]The true magnitude of AFQT effects may be even larger than reflected in our analyses. The possibility exists that soldiers who enlist for MOS 24T self-select or are chosen by military job counselors for this specialty in part because they have superior skills as Patriot operators. Such selection would restrict the range of observed outcome scores. If persons who do not currently enlist in MOS 24T were encouraged to do so in the future (for example, by lowering aptitude requirements), the extent of this screening might decrease. Using accession records, we performed a Heckman correction for selectivity, distinguishing persons enlisting in MOS 24T from persons enlisting in other Army specialties during the same time period. (See Greene, 1990, p. 744.) The predictors included AFQT score, age at entry, high school graduation status, sex, and year of entry. The correction term derived from the predicted (probit) probability of becoming a Patriot operator was then entered as an additional term with the predictor variables in our outcome regressions. The result was an increase of about 50 percent in the magnitude of the AFQT score coefficient. Given the uncertain extent to which selectivity would decrease if some additional lower quality recruits were allowed into this specialty, we chose to present the more conservative estimates of the effect of AFQT score on performance.

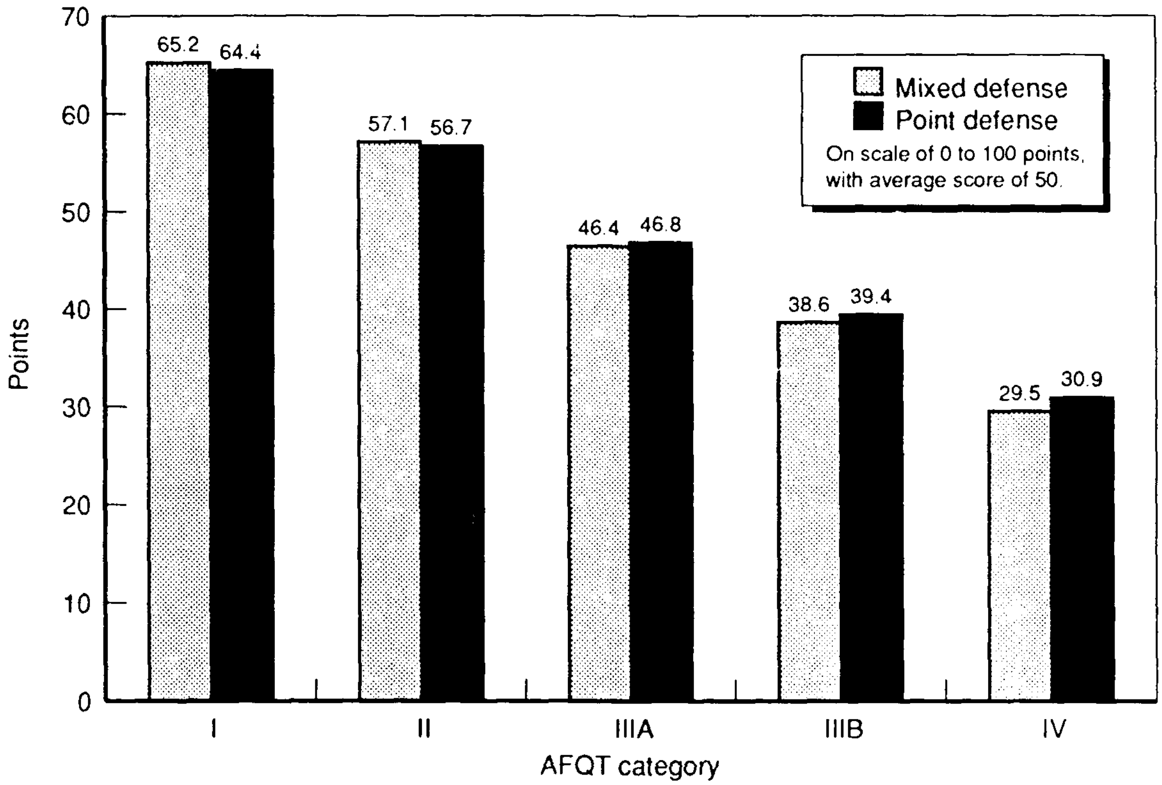


Fig. 2—Predicted Variation in Asset Defense by AFQT Category

be interpreted with caution, and we focus our discussion on the differences across categories II, IIIA, and IIIB.

The predicted variation around 50 as one moves across AFQT categories in Figure 2 is quite consistent for the two scenarios. For example, moving from category II to category IIIB in both cases shows a substantial decrease in the expected score on asset defense, from approximately 57 for category II to 39 for category IIIB. In other words, even if the category IIIB soldier had the average amount of operator experience, unit, overseas, and training values, these data predict that he would perform more poorly than most (61 percent—i.e., 100 – 39) of his fellow 24T soldiers. In contrast, the category II 24T would outperform most other 24Ts. The predicted difference between category IV and I soldiers, which cannot be estimated with as much confidence, is 35 points out of 100.

Asset Defense by Priority of Asset

The examinees were given information concerning the priorities of the assets at the beginning of each scenario. In recognition of the need for self-defense, defense of the ECS was given the highest priority level in all scenarios. In the mixed defense scenario, an additional asset, an airfield, was assigned the second priority level; in the point defense scenario, two additional assets, an airstrip and a communications link, were assigned the second and third priority levels, respectively. These features made it possible to examine the soldiers' success at defending multiple assets of different priorities.

We compared each examinee's success in defending the various assets by determining the difference in hits he sustained against each one.[9] If AFQT score did not differentially affect asset defense by priority, defense scores for all assets would be expected to increase as one moved across AFQT categories, and the rate of change would be comparable regardless of priority.

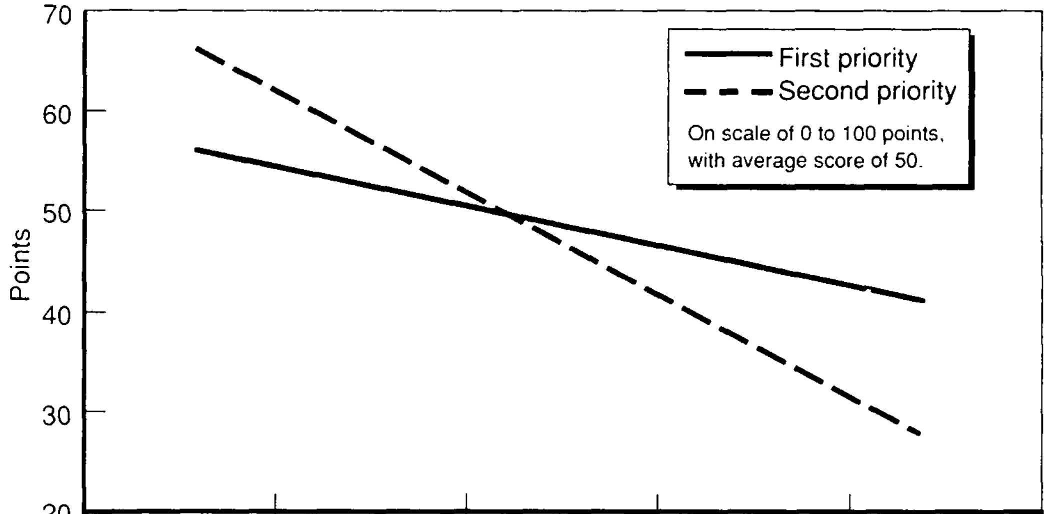
Figures 3 and 4 illustrate the AFQT results from these comparisons. First, the findings indicate that soldiers with higher AFQT scores were better able to defend all assets regardless of priority, as seen in the variation in predicted performance across AFQT categories. Second, the findings show that lower quality 24Ts had more difficulty in simultaneously defending multiple assets, as reflected in the wider variations in performance across AFQT categories for the lower priority assets. In short, AFQT score is significant in improving self-defense (i.e., defending the ECS), and its importance increases for the protection of other assigned assets.

For example, for the mixed defense scenario, there is a marginally significant relationship between AFQT score and ECS defense and a significant relationship between AFQT score and the *difference* in hits sustained on the two assets (i.e., on the importance of AFQT score for defense of the lower priority asset relative to the ECS). This pattern is replicated for the point defense scenario, for which there is a statistically significant AFQT effect on ECS defense and on the difference in hits sustained against the ECS and the second priority asset. The relationship between AFQT score and the difference in hits against the ECS and third priority asset is almost significant at the conventional level (i.e., $p = .08$).

Specifically, for the mixed defense scenario, presented in Figure 3, the predicted score in ECS defense decreases from around 53 to about 45 as one moves from category II to category IIIB, a difference of 8 points. There is a larger drop in asset defense for the second priority asset, from roughly 57 to 37, a decrease of 20 points. The results for the point defense scenario, presented in Figure 4, show a similar pattern of increasing change in predicted score for the first (9 points), second (14 points), and third (17 points) priority assets as one moves from category II to category IIIB.[10] In other words, the AFQT effect is strong for ECS

[9]This variable was operationalized in the following manner. In the mixed defense scenario, there were two assets, A2 and B2. From the number of hits against asset B2, which had a secondary priority, we subtracted the number of hits against A2, the first priority (ECS) asset: DIFB2A2 = (DAM_B2–DAM_A2). Then, this variable was standardized as a Z-score: ZDIFB2A2 = (Y_i – mean)/stddev. In the point defense scenario there were three assets, A3, D3, and E3. From the number of hits against asset E3, which had a secondary priority, we subtracted the number of hits against A3, the first priority (ECS) asset: DIFE3A3 = DAM_E3–DAM_A3). Then, this variable was standardized as a Z-score: ZDIFE3A3 = (Y_i – mean)/stddev. Similarly, from the number of hits against asset D3, which had third priority, we subtracted the number of hits against A3, the first priority (ECS) asset: DIFD3A3 = (DAM_D3–DAM_A3). Then, this variable was standardized as a Z-score: ZDIFD3A3 = (Y_i – mean)/stddev.

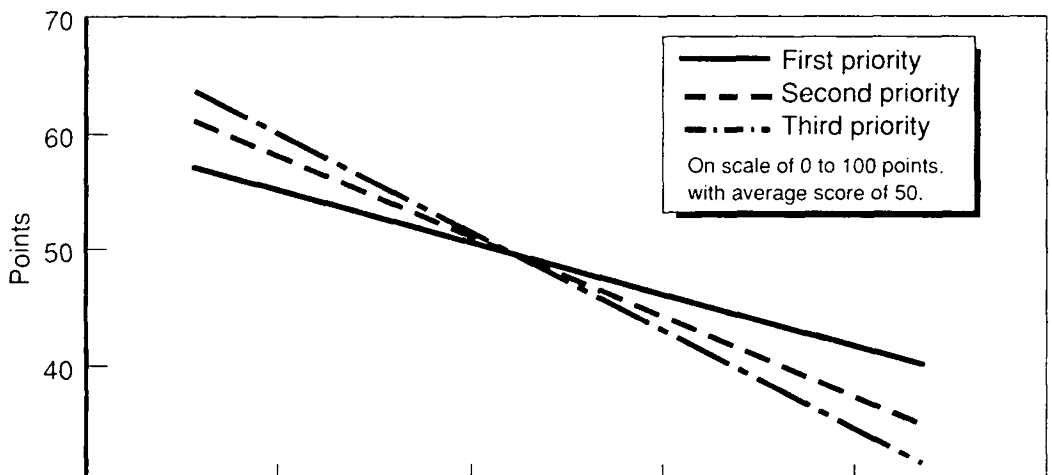
[10]One could get the impression from Figures 3 and 4 that category I examinees defended the lower priority assets better than the higher priority assets. This, however, is not the case. The figures compare the extent of change by AFQT category around the average score of 50, not absolute performance. In the mixed defense scenario, for example, the predicted number of hits for category I examinees on the first priority asset is 1.34, or 33.4 percent of the maximum attainable, whereas the predicted number of hits for category I examinees on the second priority asset is 2.35, or 39.1 percent of the maximum attainable. Thus, when looked at as the predicted number of hits on the asset as a percentage of maximum possible, the results show that category I examinees defended the first priority asset better than the second priority asset. Likewise, the percentages of maximum hits for category IV examinees on the first and second priority assets are 43.7 percent and 60.3 percent, respectively, indicating that they, too, defended the first priority asset better than the second priority asset. Note the wider range across AFQT categories on the second priority asset; this is what is reflected in the numbers shown in Figure 3.



	I	II	IIIA	IIIB	IV
First priority	56.4	52.8	48.4	45.2	41.3
Second priority	66.6	57.5	46.4	37.4	27.8

AFQT category

Fig. 3—Predicted Variation in Simultaneous Defense of Assets with Different Priorities: Mixed Defense Scenario



	I	II	IIIA	IIIB	IV
First priority	57.1	53.2	48.4	44.4	40.1
Second priority	61.0	55.2	47.6	41.7	35.2
Third priority	63.7	56.4	46.8	39.7	31.6

AFQT category

Fig. 4—Predicted Variation in Simultaneous Defense of Assets with Different Priorities: Point Defense Scenario

defense and stronger still for the simultaneous defense of lower priority assets. This finding strengthens the asset defense results presented earlier in this section, because it implies that the effect of soldier quality on the defense of assets such as airfields, ammunition depots, storage sites, and communication links (rather than self-defense of the ECS) is even larger than that shown and because the defense of such assets is *the* reason for emplacement of the Patriot battery.

Hostile Aircraft Killed in Accordance with Tactics

The outcome measure on hostile aircraft killed in accordance with tactics indicates the number of such aircraft destroyed according to tactical standing operating procedures.[11] The results for the measure are shown in Table 9, which is similar in format to Table 8.

As was true for asset defense, the first column of the table reveals the pervasive effects of soldier quality on performance. Again, the predicted change in score per AFQT category is about 7 to 10 points, a pattern similar to that found for asset defense. The other major factor in increasing tactically correct kills appears to be unit experience, which is significant in three of the four scenarios and marginally significant in the other. This finding is not surprising, since, as noted earlier, most of the tactics are taught after the student graduates from AIT. Operator experience does not have an additional effect on this outcome measure, suggesting that tactics are taught during the initial period of one's assignment to a unit. This interpretation is given some additional support by the negative result for the Germany station variable in the battalion scenario. In combination with the unit member effect, this negative result indicates that whereas the performance of personnel stationed in Germany was comparable to that of graduating AIT students, unit members at Fort Bliss had a higher predicted level of tactically correct kills when acting as TDAs. The suggestion here again is that tactics are taught soon after AIT, in a unit at Fort Bliss.[12] In the case of battalion operations, in which few soldiers would have the opportunity to act as TDAs, the information conveyed may be forgotten as time progresses (and persons are shipped overseas). Finally, regular simulation training for unit members shows a statistically significant effect in increasing kills for two of the four scenarios. Again, this result is encouraging given the probable lack of precision in the training measure. As was true for asset defense, we found that an AFQT category is worth as much as or more than a year of operator experience or frequent training in increasing kills. The readiness and cost implications of this result are similar to those noted earlier for asset defense.

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[11]As noted earlier, one might argue that the way in which a hostile aircraft is killed is of little significance. However, this is not the case. Tactical procedures are established to minimize the potential engagement of friendly aircraft and to ensure that missiles are not wasted because several fire units are engaging the same aircraft or because of multiple or needless engagements by a given fire unit. Therefore, aircraft kills in violation of tactical criteria can waste valuable resources and endanger the safety of friendly aircraft. We evaluated each engagement according to seven tactical criteria: (1) netted errors, (2) time to last launch errors, (3) asset threat code errors, (4) method of fire errors, (5) safe passage corridor errors, (6) slow speed target errors, and (7) flight path errors. (Each of these criteria was explained in Section 3.) If an examinee committed any of these errors when engaging an aircraft, the kill was deemed *not* in accordance with tactics. (Of course, it was not possible to commit each error in every scenario or for every flight.)

[12]Although direct overseas assignments after AIT have increased, they were uncommon for the MOS 24T soldier population under study.

Table 9

Summary of Regression Results for Hostile Aircraft Killed in Accordance with Tactics (predicted change in tactically correct kills on scale of 0 to 100)

	Factor				
Scenario	AFQT Category	Operator Year	Unit Member	Germany Station	Simulation Training Day Each Ten Days
Area defense (ZHIAW1)	7.2**	4.8	12.3**	0.0	5.2**
Mixed defense (ZHIAW2)	7.6**	2.4	22.7**	−1.2	−2.0
Point defense (ZHIAW3)	9.9**	4.8	10.3*	−2.0	5.2**
Battalion (ZHIAW4)	7.2**	4.4	17.7**	−13.5**	−0.8

NOTE: Single asterisk signifies a marginally significant factor ($p < .10$); double asterisk signifies a statistically significant factor ($p < .05$).

Hostile Aircraft Killed in Accordance with Tactics by AFQT Category

Figure 5 illustrates the results for hostile aircraft killed in accordance with tactics for the AFQT categories. As was true for asset defense, there is a large change in predicted success in air battles as one moves across AFQT categories. For the mixed defense scenario, the expected score on aircraft killed decreases by 13 points from category II to category IIIB; for the point defense scenario, it decreases by 18. In other words, even if soldiers were similar in operator experience, in whether they did or did not belong to a unit, in where they were stationed, and in how much training they had received, AFQT level would make a significant difference in their ability to kill enemy aircraft. A category II soldier would outperform most of his fellow 24Ts, whereas a category IIIB soldier would be outperformed by most of them. These results are highly consistent with the results found for asset defense, which attests to the underlying importance of soldier quality in the air defense mission.

Missile Conservation

The missile conservation outcome measure is the reciprocal of the average number of missiles required to destroy one hostile aircraft in accordance with tactics. The goal is a ratio value of one. To compute the measure, we tabulated the total hostile aircraft killed in accordance with tactics and the total missiles fired for a given scenario. We then divided the number of tactically correct kills by the number of missiles used.[13] The results of the multivariate regression performed on this measure are summarized in Table 10.

The overall pattern of results for missile conservation resembles that reported for hostile aircraft killed in accordance with tactics. This outcome is understandable, since number

[13]One of our tactical instructions required the use of two missiles per aircraft under certain limited conditions. In such instances, we adjusted the number of missiles used in the formula to one firing to preserve the goal of obtaining a one-to-one ratio.

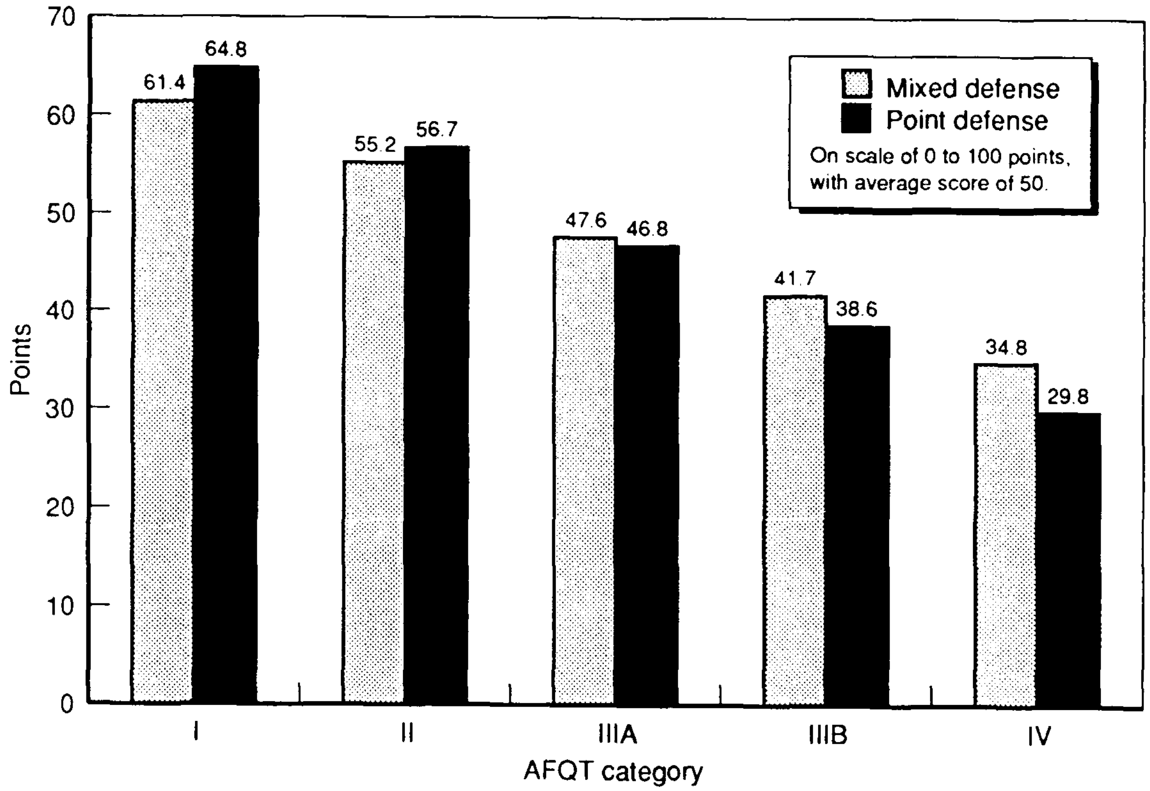

Fig. 5—Predicted Variation in Hostile Aircraft Killed by AFQT Category

Table 10

Summary of Regression Results for Missile Conservation (predicted change in missile conservation on scale of 0 to 100)

	Factor				
Scenario	AFQT Category	Operator Year	Unit Member	Germany Station	Simulation Training Day Each Ten Days
Area defense (ZMSLCON1)	6.4**	3.2	9.1	–0.8	3.6
Mixed defense (ZMSLCON2)	4.8**	1.2	20.0**	–5.2	–4.4**
Point defense (ZMSLCON3)	6.0**	0.8	17.0**	–6.8	1.6
Battalion (ZMSLCON4)	0.4	–0.8	15.4**	–16.2**	0.0

NOTE: Double asterisk signifies a statistically significant factor ($p < .05$).

of tactically correct kills is one of the two components of this variable. Again, AFQT category and unit membership show significant effects on success in the air battle. The predicted change in score by AFQT category is about 5 to 6 points—a little lower than the effect seen on asset defense and technically correct kills—and is statistically significant in three of the four scenarios. (The somewhat smaller effects reflect greater comparability across AFQT categories in the number of missiles fired than in the number of tactically correct kills.) The predicted effect of unit membership again is large, reflecting the teaching of tactics after the student graduates from AIT, and, again, there is a negative effect for Germany station in the battalion scenario. Finally, the training variable shows a significant result in only one scenario, and not in the expected direction; the basis for this result is not clear.

Missile Conservation by AFQT Category

Figure 6 illustrates the results for predicted missile conservation by AFQT category. For the mixed defense scenario, the expected performance in missile conservation declines by 9 points as one moves from category II to category IIIB; for the point defense scenario, it declines by 10. While these differences are not as dramatic as those reported for asset defense and tactically correct kills, the AFQT effect is still substantial. For example, when converted to the predicted number of missiles required for ten tactically correct kills, the impact of AFQT score is clear. The model predicts that a category I soldier will fire 17.6 and 20.3 missiles to kill ten targets in the mixed and point defense scenarios, respectively. These figures change to 19.8 and 24.1 missiles for a category IV soldier in the same scenarios, an increase of 2.2 and 3.8 missiles. Given the difficulties of resupply in wartime and the cost of each missile (approximately $570,000), this difference seems noteworthy.

Summary Measure of Primary Outcomes: Battlefield Survival

The summary measure of the primary outcomes, battlefield survival, assesses a soldier's overall success in fighting the air battle at the battery level. It combines his performance in asset defense, hostile kills in accordance with tactics, and missile conservation in the area, mixed, and point defense scenarios into one score. To compute it, the Z-scores obtained by a soldier on the three measures were combined for each scenario. The resulting score was then standardized across soldiers so that its mean was 0 and the standard deviation was 1. Finally, the resulting scenario score was summed across the three battery scenarios for each soldier, and the overall sum was converted to a Z-score. This procedure gives equal weight to each measure and each scenario in determining the overall results. We excluded the battalion scenario because we believe the TDA role differs in important ways from the TCA role, as reflected in the difficulty most examinees experienced in this air battle.

The regression results for the overall measure are summarized in Table 11. The results leave little doubt concerning the direct effect of soldier quality and unit training on battlefield success. The AFQT category, operator experience, and unit member effects are all statistically significant, and the training effect is marginally significant. As before, the AFQT result has readiness and cost implications, because the effect of increasing aptitude by one AFQT category is estimated to be equal to or larger than that associated with a year of operator experience or regular simulation training in improving success in air battles. The training result is encouraging nonetheless, given the imprecision of the measure. Overall,

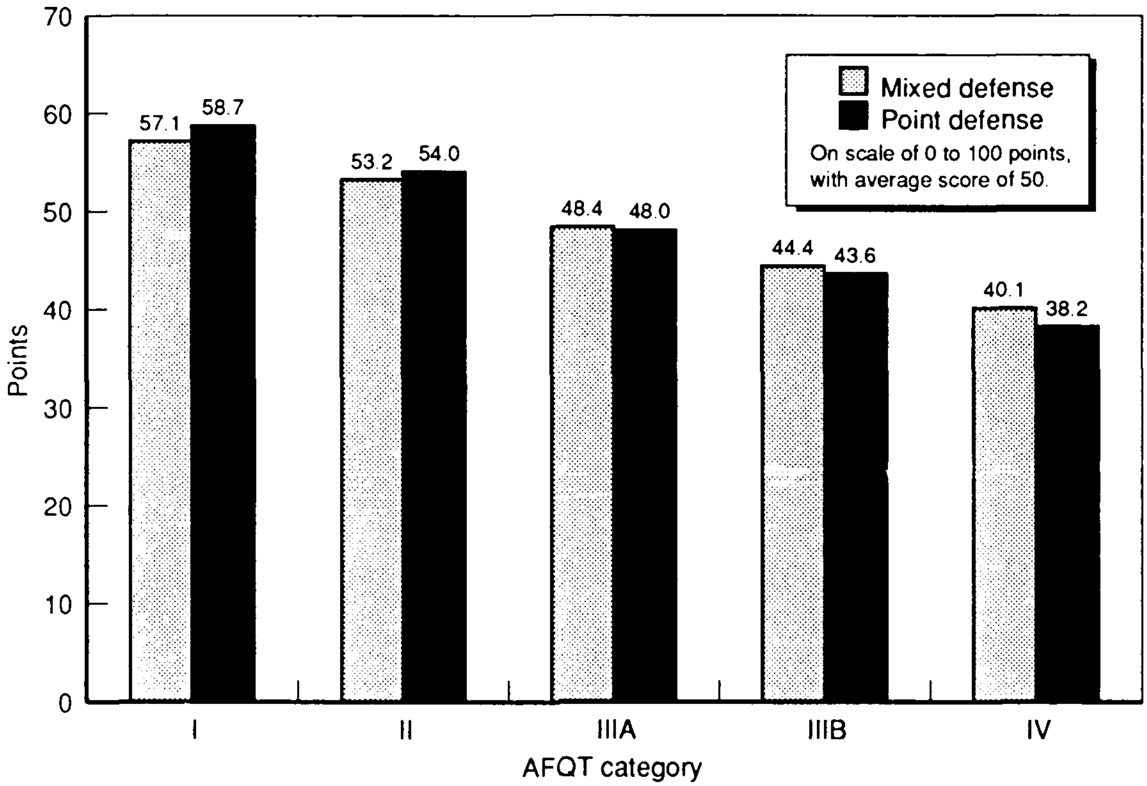

Fig. 6—Predicted Variation in Missile Conservation by AFQT Category

the results suggest that once tactics have been taught to a new unit member, his aptitude (i.e., quality) has the most direct effect on his success in fighting an air battle. It appears to take a considerable amount of experience and training to compensate for aptitude differences—experience and training that, if invested in soldiers of greater aptitude, could result in even higher levels of performance.

Table 11

Summary of Regression Results for Battlefield Survival (predicted change in battlefield survival on scale of 0 to 100)

	Factor				
Measure	AFQT Category	Operator Year	Unit Member	Germany Station	Simulation Training Day Each Ten Days
Battlefield survival (PTACPRO)	11.9**	6.8**	15.8**	−1.2	4.4*

NOTE: Single asterisk signifies a marginally significant factor (p < .10); double asterisk signifies a statistically significant factor (p < .05).

Battlefield Survival by AFQT Category

The results for predicted battlefield survival by AFQT category are illustrated in Figure 7. There is a large decrease in predicted score as one moves across AFQT categories: expected performance decreases by 22 points from category II to category IIIB. This decrease is similar to the largest of the differences shown earlier. It clearly indicates that there is a major improvement in performance on the primary air battle functions as soldier quality (i.e., AFQT score) increases.

Friendly Aircraft Killed

The number of friendly aircraft killed by examinees was very small: 0.0, 0.7, 0.6, and 0.0 in the area defense, mixed defense, point defense, and battalion scenarios, respectively. As a result, virtually no significant effects were found for any of the predictor variables. Specifically, there were only two significant relationships: operator experience had a significant effect on reducing the number of friendly kills in the point defense scenario, and unit experience significantly reduced the number of friendly kills in the area defense scenario. We attribute the low number of kills at least in part to the limited number of electronic iden-

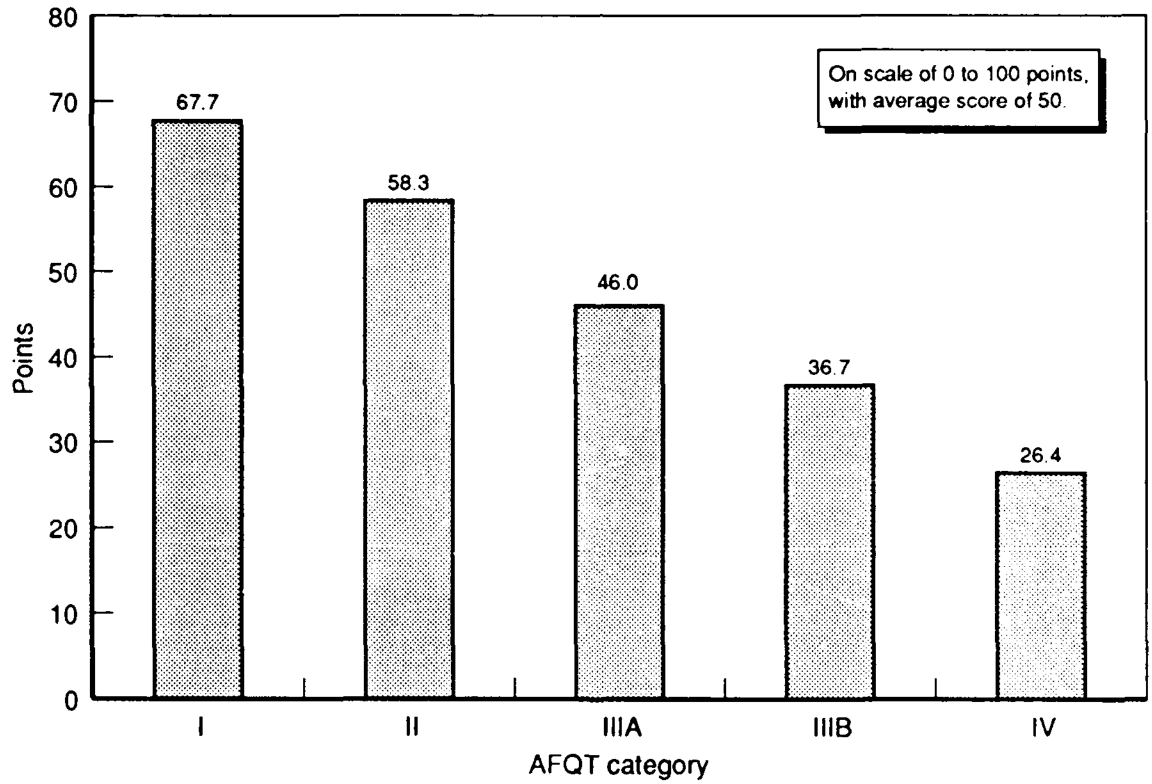

Fig. 7—Predicted Variation in Battlefield Survival by AFQT Category

tification problems built into the scenarios and to the fact that friendlies generally complied with air space control procedures in their flight patterns. To the extent that these conditions might differ in actual combat, the results could change as well.

UNSTANDARDIZED OUTCOME MEASURE SCORES BY AFQT CATEGORY

The discussion to this point has concerned the effect of the predictor variables on standardized outcome measures. As noted, standardization allowed us to meaningfully compare the effects of the predictor variables across different outcome measures and scenarios by giving us a way to deal with idiosyncratic differences in the air battle simulations. Standardization thus permitted a more thorough consideration of the results. A consequence of standardization, however, is that performance on raw outcome measures, such as the number of hits sustained against protected assets or the number of enemy aircraft killed, is not readily apparent. To illustrate the very substantial effect of AFQT score on the raw outcomes, we conclude this section with a brief review of soldier performance on such measures by AFQT category. Specifically, Figures 8, 9, and 10 show the predicted effect of AFQT score on asset damage, aircraft kills in accordance with tactics, and missile usage as determined by OLS regressions using the established predictor variables and raw (unstandardized) outcome scores. These three measures make up the summary measure of battlefield survival. As was true for that summary measure, the results for the three battery scenarios were combined to make them more amenable to generalization.

Total Asset Damage by AFQT Category

In examining asset *defense* by AFQT score, we observed that AFQT score had a significant effect on the ability to defend assets in each battery level scenario. We here combine the results for those three air battles and examine the effect of AFQT score on the number of hits sustained against the ECS and any defended assets (DAMAGE in Appendix A). A *hit* is simply a sustaining of damage from a hostile aircraft (by bomb or missile).

As seen in Figure 8, AFQT score has a significant effect on this outcome measure, on the order of a 5 to 10 percent difference in asset damage by AFQT category. Specifically, the estimated number of enemy hits sustained by a category II soldier with average experience and training is 11.2 (of 28 maximum). This number increases by about one hit per AFQT category, to 13.2 hits for category IIIB soldiers.

Total Tactically Correct Kills by AFQT Category

The effect of AFQT score on the number of hostile aircraft killed in accordance with tactics (HIAW in Appendix A) is shown in Figure 9. Similar to the results for total asset damage, the predicted number of tactically correct aircraft kills changes by 5 to 10 percent across categories. Specifically, the estimated number of kills for a category II soldier is 50.7 (of 78). This number decreases by about three aircraft per AFQT category, to 44.9 for soldiers in category IIIB.

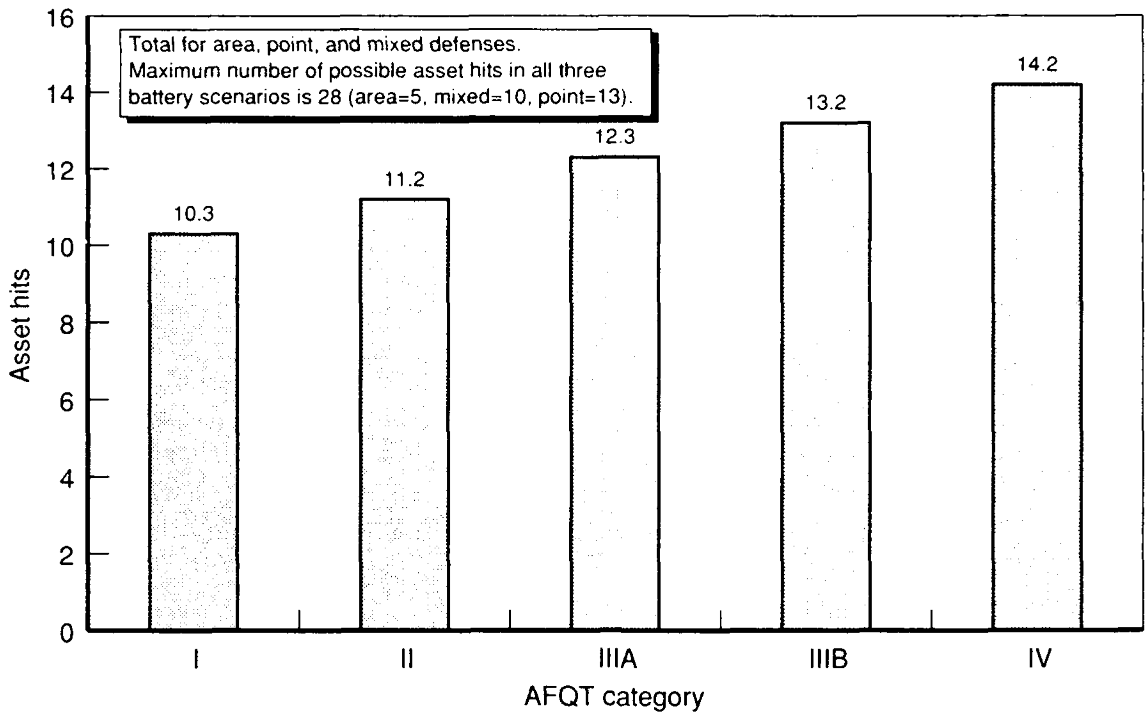

Fig. 8—Predicted Asset Damage by AFQT Category

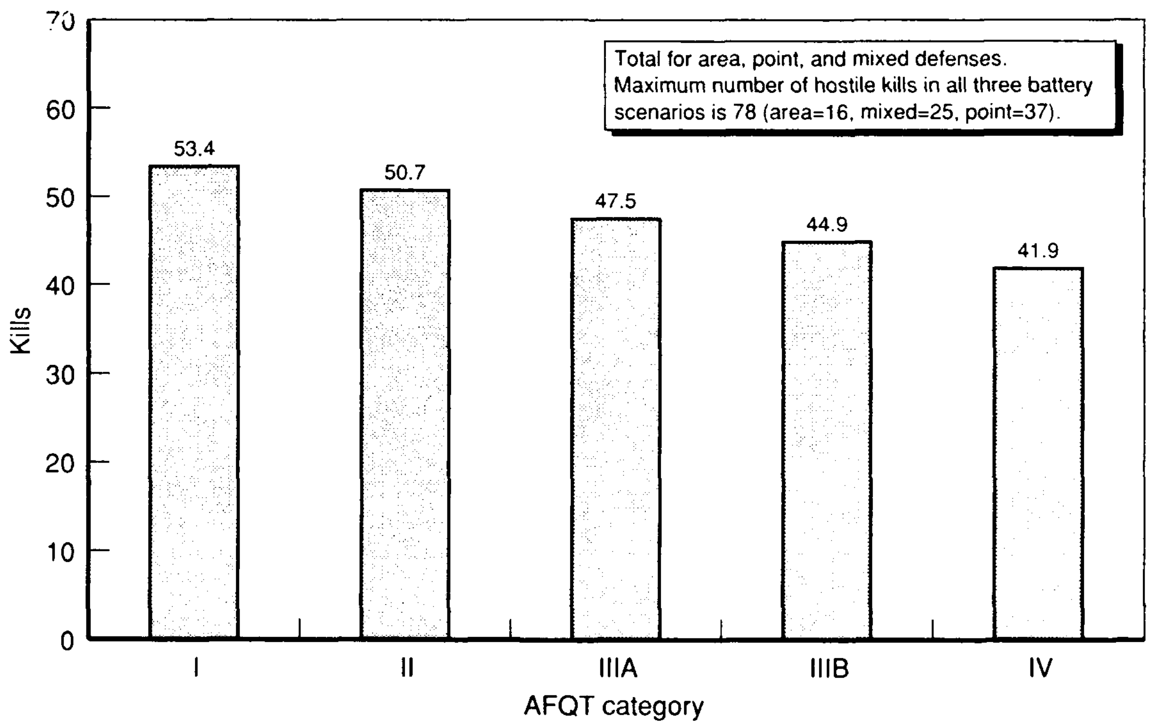

Fig. 9—Predicted Tactically Correct Kills by AFQT Category

Missiles Used per Ten Hostile Kills

The results for the third primary outcome measure, ratio of missiles used per hostile aircraft killed in accordance with tactics (MSLCONS in Appendix A), are illustrated in Figure 10. Again, AFQT score has a significant effect, in this case about 5 percent per category. The regression predicts that a category II soldier with average experience and training will fire about 20.8 missiles for every ten tactically correct kills. Predicted missile usage increases by about one missile per category, to 22.7 for category IIIB soldiers.

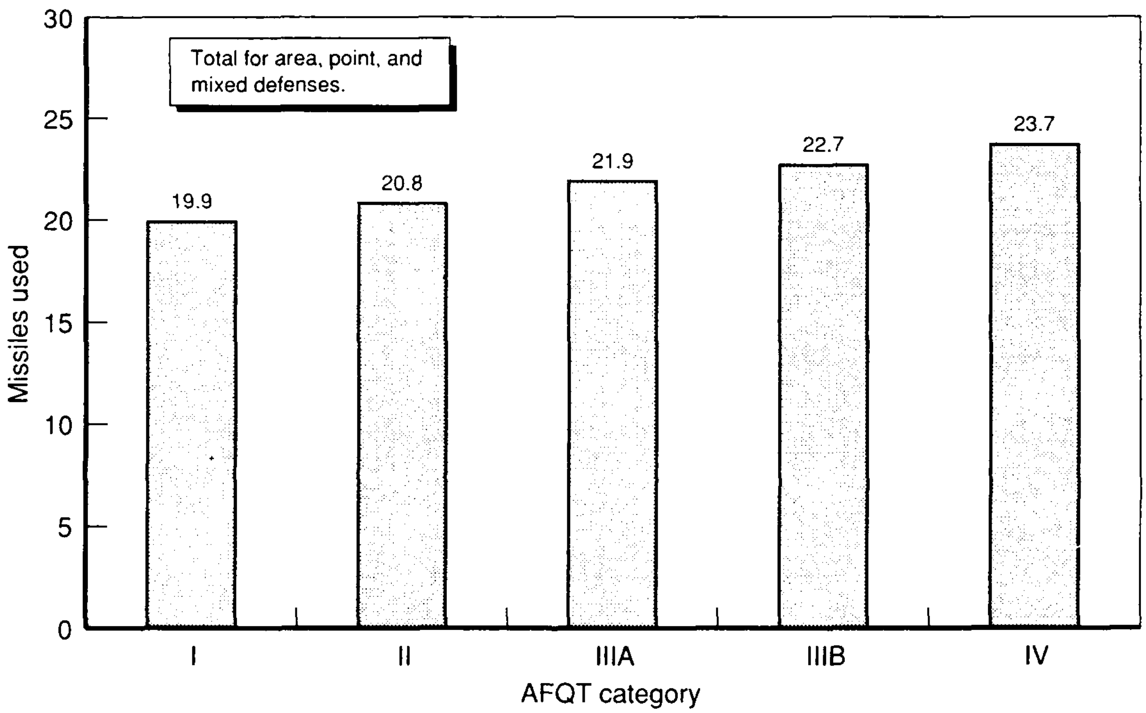

Fig. 10—Predicted Missiles Used for Ten Tactically Correct Kills

5. RESULTS FOR SUPPORTING MEASURES

Patriot operators must perform numerous individual tasks and make numerous judgments that *collectively* result in the battlefield outcomes assessed by our primary measures (e.g., asset damage and hostile aircraft kills). Some of these tasks and judgments are more *tactical* in nature, such as using the appropriate method of fire and complying with requirements for engaging aircraft representing specified types of threats. Others are more directly concerned with *technical* ability, such as console setup, engagement of battalion-specified targets, and execution of IFF code bank changes. In this section, we present results for key tasks and judgments that contribute to success on our primary measures. We begin with a brief review of these supporting measures, which are defined more fully in Section 3.

The three tactical supporting measures evaluated were as follows:

1. *Tactical correctness of engagements:* There are various tactical procedures with which operators must comply while engaging aircraft. Each engagement was evaluated according to the following criteria, which were developed for the purpose of the test:[1]
    a. Netted error—engaging an aircraft without authorization while in the centralized mode of operation.
    b. Method of fire error—improper (in number and/or timing) missile firing given specified tactics, flight size (number of aircraft), and type of threat.
    c. TLL error—firing at an aircraft too far away.
    d. Asset threat code error—engaging an aircraft not threatening defended assets.
    e. Safe passage corridor error—engaging an aircraft in a safe passage corridor.
    f. Crossing and outbound error—engaging a crossing or outbound aircraft not posing a specified type of threat or in violation of missile conservation orders.
    g. Slow speed error—engaging a slow speed target not threatening the ECS or too far away.
2. *Success in manual identification procedures:* Success in identifying five hostile aircraft flying in a compromised safe passage corridor.
3. *Tactical Standing Operating Procedures (TSOP) written exam:* Score on the written tactics test.

The five technical measures evaluated were as follows:

1. *Execution of IFF code change:* Timely and correct entry of newly specified IFF code information.
2. *Execution of engagement, cease fire, and hold fire commands:* Compliance with orders to engage, cease fire, or hold fire on specific aircraft during centralized operation.
3. *Console status:* Compliance with instructions for console setup (final check).

[1]It is not always possible to commit all of these errors on one engagement.

4. *Launching station status:* Compliance with instructions for launching station setup (final check).
5. *Initialization written test:* Score on the written initialization test.

Because the Air Defense School wanted to summarize the supporting measure results according to their implications for tactical and technical proficiency, we converted the results for individual supporting measures to Z-scores (to give them equal weight) and added them together. The resulting summary measures, which were converted to Z-scores and combined for the three battery level scenarios, were as follows:

1. *Tactical proficiency:* Compliance with individual tactical criteria during the air battles, including netted, method of fire, TLL, and asset threat code criteria and manual identification success.[2]
2. *Technical proficiency:* Performance in setting up the console and launchers, complying with engagement commands, and executing the IFF code bank change, and score on the written initialization test.[3]

MEAN, MINIMUM, AND MAXIMUM SCORES

Summary statistics for the supporting output measures are presented in Table 12.[4] Generally, unit members performed at a higher level of proficiency than AIT students, as was true for the primary outcome measures (see Section 4). However, not all of the differences are statistically significant, and, as was true for the primary measures, most of the variation in performance occurs across individuals, rather than between AIT students and unit members.[5]

Overall, performance levels were higher on the tactical measures than on the technical measures. For example, the percentage correct on most of the tactical measures is in the 70 to 80 percent range; on the technical measures, the range is about 50 to 75 percent for most measures. The regression results (see below) help to explain this difference. The scores on two of the tactical measures (manual identifications and TSOP written test) and two of the technical measures (IFF code change and initialization written test) are substantially lower than the rest of the scores in each group. The written tests were specifically designed to produce a mean score of about 50 percent correct (to improve the measurement of individual performance differences), so the lower scores on the written tests do not indicate poorer performance relative to other measures. However, the IFF procedures and, especially, the

[2]We used the error rate per engagement. Safe passage corridor, slow speed target, and flight path errors were excluded because of their infrequent occurrence, which made it difficult to reliably estimate their relationship to other variables and also argued against weighting them equally with the other measures. The written tactics test score was excluded because the test was taken only by unit members.

[3]Compliance with cease and hold fire orders was excluded because of their infrequent occurrence, which made it difficult to reliably estimate their relationship to other variables and also argued against weighting them equally with the other measures.

[4]Results for the indices excluded from the summary measures can be found in Appendix A. The percentage for authorized engagements was derived by dividing the number of netted errors committed by 12 (the maximum possible), subtracting this proportion from one, and converting the result to a percentage figure.

[5]We discuss this issue in more detail below, under Regression Results.

Table 12

Mean, Minimum, and Maximum Scores for Supporting Measures[a] (in percent correct)

Measure	AIT Students Mean	AIT Students Min	AIT Students Max	Unit Members Mean	Unit Members Min	Unit Members Max
Tactical Measures						
Authorized engagements (netted errors)	65.0	16.7	100.0	75.0	0.0	100.0
Manual identifications	33.4	0.0	100.0	30.0	0.0	80.0
Method of fire	79.7	53.8	92.5	80.9	53.1	94.1
Time to last launch	81.3	48.9	100.0	87.3	48.5	100.0
Asset threat code	75.8	37.7	100.0	82.1	36.7	100.0
TSOP written test	—	—	—	53.2	4.0	92.0
Technical Measures						
IFF code bank change	30.3	0.0	100.0	59.5	0.0	100.0
Engagement compliance	47.4	0.0	100.0	67.7	0.0	100.0
Console setup	58.3	0.0	100.0	67.2	0.0	100.0
Launcher setup	77.1	0.0	100.0	77.7	0.0	100.0
Initialization written test	43.1	20.0	64.0	53.8	20.0	96.0

[a]Reading down, the standard deviations for the AIT student means are 22.6, 23.6, 6.2, 12.7, 15.9, 46.2, 36.5, 34.2, 26.7, and 9.5; and for the unit member means, 23.2, 23.9, 6.8, 10.1, 13.9, 19.1, 49.2, 35.0, 31.3, 30.1, and 15.9. The number of cases varied slightly but was generally about 92 for AIT student measures and 215 for unit member measures. There is little evidence of heteroscedasticity; only the time to last launch and initialization written test measures produced statistically different standard deviations for AIT students and unit members.

identification procedures may have been more difficult, contributing to the lower scores. It is also likely that the lower scores on these tasks can be attributed to the fact that the tasks had to be performed while (i.e., in addition to) fighting the air battle.

REGRESSION RESULTS

Table 13 summarizes the results of our regression analyses for the individual and summary supporting measures. The supporting measures listed were converted to Z-scores, as was done for the primary output measures, and then scaled so that a higher number implies better performance than a lower number. Over the various measures, we obtained significant effects for each of the factors in the regression model. As was true for the primary air battle outcomes, we found that AFQT score showed a greater number of significant effects on performance than any other predictor variable. The next most dominant variable was operator experience. This pattern was particularly true for the technical measures. For several tactical measures, unit membership also appears to have large effects on performance. These results are discussed more fully below. We note here, however, that these results are *not* simply restatements of the earlier results for the battlefield survival measures. With the exception of the pairing of tactical proficiency and battlefield survival, which shows a correlation of .86, the correlations among the survival, tactical, technical, initialization, and TSOP measures range from .24 to .55. (The correlations are shown in Appendix A.)

Table 13

Summary of Regression Results for Supporting Measures (predicted change in score on scale of 0 to 100)

	Factor				
Measure	AFQT Category	Operator Year	Unit Member	Germany Station	Simulation Training Day Each Ten Days
Tactical Measures					
Authorized engagements (ZNETER1)	3.6	8.0**	7.6	5.2	1.6
Manual identifications (ZMANALID)	5.6**	5.6	–4.4	–12.7**	2.8
Method of fire (ZMOF1,2,3)	8.8**	6.4**	0.4	1.2	0.8
Time to last launch (ZTLL1,2,3)	6.0**	2.8	15.4**	–4.4	3.2
Asset threat code (ZATC3RAT)	0.8	–1.6	20.4**	–6.8	1.6
TSOP written test (ZTPERCOR)	7.2**	27.7**	—	–4.8	1.2
Tactical summary measure (STACPRO)	9.5**	6.4**	17.7**	–6.0	2.8
Technical Measures					
IFF code bank change (ZIFFCO3)	7.6**	16.2**	8.8	4.0	0.8
Engagement compliance (ZCOMPLY1)	4.8**	7.2**	11.5**	2.8	5.2**
Console setup (ZCON110)	4.8*	8.0**	2.8	4.4	0.0
Launcher setup (ZLNCH110)	9.1**	–1.6	0.0	0.0	2.8
Initialization written test (ZIPERCOR)	11.9**	19.0**	2.4	13.9**	6.0**
Technical summary measure (TEKPROF)	11.1**	11.5**	2.4	13.1**	2.8

NOTE: Single asterisk signifies a marginally significant factor ($p < .10$); double asterisk signifies a statistically significant factor ($p < .05$).

Tactical Measures

AFQT score showed statistically significant effects on four of the six individual tactical measures and on the tactical summary measure. An increase of one AFQT category resulted in a 5 to 10 point increase in performance on these supporting measures, a result similar to that seen for the primary air battle outcomes. Operator experience and unit membership also were important. Generally, a year of operator experience had almost as much effect on performance as an increase of one AFQT category. In the case of tactical knowledge (TSOP test), the effect of operator experience was very large. Unit members showed far superior performance to AIT students on two of the tactical engagement criteria: time to last launch and asset threat code. This effect is visible in the summary measure (and is reflected in the post-AIT improvement in tactically correct kills discussed in Section 4), because time to last launch and asset threat code errors are central components of this measure. It appears that these particular elements of tactics are taught soon after AIT, upon arrival in one's unit. The remaining tactical elements appear to be learned more gradually. Finally, the 24Ts in Germany had less success in making manual identifications; the explanation for this result is unclear.

Technical Measures

Just as it did for the tactical supporting measures, AFQT score exercised a strong effect on the technical supporting measures, showing a significant or nearly significant effect on each one. Again, increasing AFQT score by one category typically improved performance by about 5 to 10 points.[6] For the technical measures, however, operator experience increased somewhat in importance relative to AFQT score and unit membership. A year of operator experience was associated with a change in outcome equal to or larger than that associated with an increase of one AFQT category (a result not obtained for other measures). The findings suggest that the technical tasks are learned through practice, whereas (some of) the tactical criteria represent concepts that can be conveyed upon arrival in the unit.[7]

Finally, the other predictor variables were found to have significant effects on some of the technical supporting measures. Most notably, frequent simulation training appears to improve compliance with engagement orders and knowledge of initialization procedures. Initialization also appears to be stressed after assignment overseas.

Supporting Output Measures by AFQT Category

The predicted results at the AFQT category midpoints for the tactical and technical summary measures and for the TSOP written test are illustrated in Figure 11. As was true for the primary measures, there is a large decrease in expected performance as one moves across AFQT categories; expected performance again decreases by about 5 to 10 points per category. The results are highly similar for the two air battle measures and the written test.

Implications for Training

Unlike the primary outcome measures, which reflect numerous simultaneous actions, the supporting outcome measures represent discrete tasks. As a consequence, implications for training may be extracted more directly. Tables 12 and 13 provide error rate information

[6]The IFF code bank change outcome measure is dichotomous. For such variables, use of OLS regression can result in predicted probabilities of success that are above 1 or below 0. For this reason, probit or logistic analyses often are used instead. However, use of OLS regression has little influence on the effects of primary interest in our analysis: the significance levels and comparative effects of the predictor variables remain (essentially) unchanged, and the predicted differences across AFQT categories also are comparable. For example, the predicted probability of success on the IFF measure across the AFQT categories declines by 36 points from category I to category IV using OLS regression and by 39 points using probit analysis. Thus, the per-category change and associated score differences are highly similar for the two approaches. Given this similarity and the greater ease of obtaining and interpreting predicted results using OLS, we used this procedure throughout.

[7]We found that operator experience played a particularly important role in improving performance on technically oriented tasks. We believe that the improvement stems from the fact that these tasks require frequent practice to develop greater proficiency. It is possible, however, that certain soldiers are selected to become operators because they possess certain skills or characteristics. We tested for this possibility by introducing the separate aptitude composite scores (e.g., CO, EL, MM, etc.) into our basic model. If there is some fundamental dimension along which operator skill characteristics can be captured, introduction of the composites should diminish the effect of operator experience by absorbing its portion of the explained variance. We examined this effect for 12 separate outcomes—all of the fire battery asset defense, hostile aircraft killed, and missile conservation measures, and battlefield survival, tactical proficiency, and technical proficiency. We found that the effect of operator experience increased in eight models and decreased in four. With one exception, all operator coefficients that were significant in the standard models were also significant in the models in which the composites were included. Therefore, even though the results of this procedure are not conclusive, they strongly suggest that operator experience does contribute to improved performance.

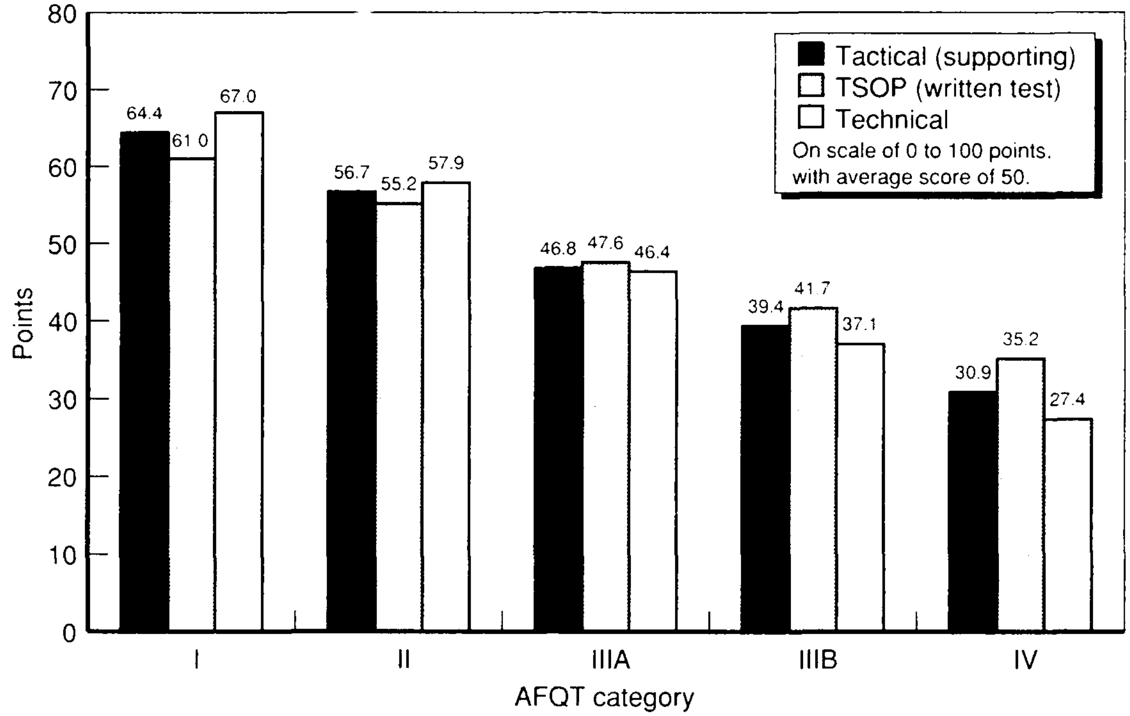

Fig. 11—Predicted Variation in Proficiency Level by AFQT Category

that should be useful in this regard; we briefly review and comment on that information here.

As noted, technical proficiency was lower than tactical proficiency. The results shown in Tables 12 and 13 suggest that more experience (i.e., practice) is required to improve technical skills, and they further suggest that simulation training may be helpful in accomplishing this goal, at least for some of the measures. Particular attention might be given to tab changes such as the IFF code change. Moreover, to the extent that performance on this measure suffered because examinees were simultaneously required to fight the air battle, it might be fruitful to focus on multiple-task training. Indeed, just as was the case for defending multiple assets, the AFQT effect in improving IFF code change performance may be partly attributable to the need to simultaneously perform multiple tasks.

With respect to tactics, it appears that certain concepts, such as waiting until an aircraft is close before firing (TLL) or matching the type of threat requiring engagement with the type of air defense mission, can be readily taught after AIT. Other concepts, such as proper use of multiple methods of fire or specific tactical nuances, may require more experience before they become second nature to an operator. Manual aircraft identification procedures in particular may require special emphasis. Normally, the system makes identifications automatically, and it is the 14E officer's job to verify them. Thus, it is possible that this task might not only be more difficult, but also may be subject to skill decay because of limited practice. Finally, here too, the results suggest that training in simultaneous performance of multiple tasks might be beneficial.

6. CONCLUSIONS

The impetus for this research was a congressional desire to empirically ascertain the extent of linkage between soldier quality and soldier performance on wartime outcome measures. At the heart of this question lies the issue of whether the additional resources required to recruit high quality youth translate into superior performance of wartime missions. The military's arsenal of sophisticated weapon and support systems offers great potential for combat effectiveness. However, realization of this potential depends on the quality of the Army's people and the training opportunities they receive. In recent years, the Army has enjoyed unprecedented levels of quality among its recruits and increased levels of experience and training among its more senior personnel. But growing constraints on the defense budget are likely to limit the Army's future ability to secure the number of high quality recruits to which it has become accustomed and to maintain its current level of training resources. As decisionmakers apply increasing levels of scrutiny to the defense budget, the need to examine resource allocations in terms of combat effectiveness and the related cost implications becomes increasingly important.

This report addresses the relationship between soldier quality and combat performance. The analysis we conducted to assess this relationship concentrated on the performance of junior (grades E1 to E5) MOS 24T soldiers on wartime-related outcomes for the Patriot missile system, the most modern air defense system in the Army's inventory. Additional supporting measures evaluated included compliance with and knowledge of tactics, and compliance with and knowledge of technical procedures. We modeled the effects of various soldier characteristics (e.g., aptitude score, training history, and assignments in Patriot jobs) on these performance measures.

The results of our analysis provide strong evidence that soldier quality, as assessed by AFQT score, has a direct and consistent effect on air battle outcomes, i.e., on the combat performance of MOS 24T personnel. The number of significant effects found for AFQT score surpasses the number of significant effects found for the other variables in the analysis. Moreover, the AFQT score effects were found consistently for the various aspects of the 24T's battery level mission—asset defense, engagement of hostile aircraft, missile conservation, tactical proficiency, technical proficiency, and knowledge of proper tactical and initialization procedures.

In general, we found a 5 to 10 percent difference in performance between adjacent AFQT categories. Thus, for example, if a category IIIA soldier is used instead of a category IIIB, or a category II soldier instead of a category IIIA, the anticipated increase in asset protection or destruction of enemy aircraft is on the order of 5 to 10 percent, both in absolute terms and relative to the performance of other soldiers. We also found substantial tradeoffs between AFQT and both operator experience and training days: an increase of one AFQT category equals or surpasses the effect of a year of operator experience or of frequent training. This finding carries readiness and cost implications, because it suggests that higher quality soldiers require less training and operator experience to perform at the same level as lower quality soldiers. Moreover, if higher quality soldiers were used and it were possible to apply some of the resultant resource savings to increase their experience or training, the result would be even better performance.

Unit membership was also very important and was second only to AFQT in its consistent ability to affect performance. It especially affected tactical performance, the reason being that tactics are taught in the units, upon graduation from AIT. We also found that operator experience had significant effects, particularly on success in asset defense. Finally, despite the limitations of our training measure, we found some evidence that significant effects can be gained from unit training consisting of practice using simulations such as the Troop Proficiency Trainer and the Live Air Trainer. These results are encouraging in that they link simulation training to wartime outcomes. Together, the operator, unit, and simulation effects lend support to the efficacy of unit training.

Our findings are especially salient in an environment of constrained resources. The results suggest that the increase in job performance and efficiency displayed by high quality soldiers produces an increase in resource savings that exceeds the concomitant cost increase associated with recruiting high quality soldiers. For example, recent work suggests that it costs about $4500 more to recruit a high quality soldier than a low quality soldier.[1] However, a corresponding savings in potential resource losses and related stockage costs is realized because of the high quality soldier's more proficient job performance.

This tradeoff between recruitment costs and resource savings can be illustrated by examining missile conservation.[2] For example, the combined results for the three battery scenarios (area defense, mixed defense, and point defense—see Figure 10) lead us to expect a category I through IIIA soldier to fire 21 missiles to destroy ten hostile aircraft in accordance with tactics. A low aptitude soldier would be expected to fire just over 23 missiles to kill the same number of aircraft. Since one Patriot missile costs approximately $570,000, the lower quality soldier expends over $1.1 million more than the higher quality soldier *for each ten aircraft*. Moreover, the data suggest that the additional training and experience required to bring the low quality soldier to the same level as the high quality soldier represent not only substantial real costs, but significant opportunity costs as well. Were the high quality soldier provided with a similar amount of augmented training and experience, he would perform at even higher levels—i.e., the performance gap between him and the lower quality soldier would remain. A corresponding analysis conducted for asset defense using the replacement cost of destroyed assets (see Appendix B) had much the same result. While it must be remembered that such analyses are intended to be illustrative of wartime requirements (they do not, for example, deal with the possibility that some 24T operators might not be used as such in actual combat), the difference between projected savings and recruitment costs is sufficiently large to make the implications of the results clear.

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[1]This figure is based on work described in Polich, Dertouzos, and Press, 1986; and in Dertouzos et al., 1989.

[2]Refer to Appendix B for a more complete explanation of how these figures were determined.

Appendix A
SUPPLEMENTARY TABLES

This appendix provides a glossary of variable names (Table A.1); the means, minimum values, maximum values, and standard deviations of the predictor and outcome variables used in the analyses (Table A.2); the correlations among the predictor and outcome variables (Table A.3); reliability (alpha) coefficients for the summary measures (Table A.4); and the regression analyses on which the results reported in the main text are based (Table A.5). The coefficients in Table A.5 indicate the predicted change on the specified outcome measure for a change of one AFQT percentile point, one month of operator experience, having progressed past AIT into a unit, each training day in the preceding 6 months, and being stationed in Germany as compared to CONUS (Fort Bliss). For unit members in Germany, the total difference in predicted performance as compared to that for graduating AIT students is represented by the sum of the unit and location coefficients; for unit members at Fort Bliss, it is simply the unit coefficient. Finally, for battalion scenario measures, the TDAMAINT coefficient indicates the effect of current TDA assignment for the small number of persons reporting same. This variable showed no significant results and thus was not reflected in the summary tables in the main text.

Table A.1

Glossary of Variables

VARIABLE	LABEL
ZDAMAGE1	ASSET PROTECTION, SCENARIO 1
ZDAMAGE2	ASSET PROTECTION, SCENARIO 2
ZDAMAGE3	ASSET PROTECTION, SCENARIO 3
ZDAMAGE4	ASSET PROTECTION, SCENARIO 4
ZDAM_A2	ASSET PROTECTION, ASSET A, SCENARIO 2
ZDAM_B2	ASSET PROTECTION, ASSET B, SCENARIO 2
ZDAM_A3	ASSET PROTECTION, ASSET A, SCENARIO 3
ZDAM_D3	ASSET PROTECTION, ASSET D, SCENARIO 3
ZDAM_E3	ASSET PROTECTION, ASSET E, SCENARIO 3
ZDAM_A4	ASSET PROTECTION, ASSET A, SCENARIO 4
ZDAM_B4	ASSET PROTECTION, ASSET B, SCENARIO 4
ZDAM_C4	ASSET PROTECTION, ASSET C, SCENARIO 4
ZDAM_D4	ASSET PROTECTION, ASSET D, SCENARIO 4
ZDAM_E4	ASSET PROTECTION, ASSET E, SCENARIO 4
ZDIFB2A2	DIFFERENCE IN ASSET PROTECTION, ASSETS A & B, SCENARIO 2
ZDIFD3A3	DIFFERENCE IN ASSET PROTECTION, ASSETS A & D, SCENARIO 3
ZDIFE3A3	DIFFERENCE IN ASSET PROTECTION, ASSETS A & E, SCENARIO 3
ZDIFD3E3	DIFFERENCE IN ASSET PROTECTION, ASSETS D & E, SCENARIO 3
ZHOKILL1	HOSTILE AIRCRAFT KILLED, SCENARIO 1
ZHOKILL2	HOSTILE AIRCRAFT KILLED, SCENARIO 2
ZHOKILL3	HOSTILE AIRCRAFT KILLED, SCENARIO 3
ZHOKILL4	HOSTILE AIRCRAFT KILLED, SCENARIO 4
ZHIAW1	HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIO 1
ZHIAW2	HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIO 2
ZHIAW3	HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIO 3
ZHIAW4	HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIO 4
ZFRKILL1	FRIENDLY AIRCRAFT KILLED, SCENARIO 1
ZFRKILL2	FRIENDLY AIRCRAFT KILLED, SCENARIO 2
ZFRKILL3	FRIENDLY AIRCRAFT KILLED, SCENARIO 3
ZFRKILL4	FRIENDLY AIRCRAFT KILLED, SCENARIO 4
ZMSLCONS1	MISSILES PER HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIO 1
ZMSLCONS2	MISSILES PER HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIO 2
ZMSLCONS3	MISSILES PER HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIO 3
ZMSLCONS4	MISSILES PER HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIO 4
ZIPERCOR	INITIALIZATION WRITTEN TEST, PERCENT CORRECT
ZTPERCOR	TACTICAL SOP WRITTEN TEST, PERCENT CORRECT
ZNETER1	NETTED ERRORS, SCENARIO 1
ZMANUALID	MANUAL IDENTIFICATIONS, SCENARIO 3
ZCOMPLY1	ENGAGEMENT COMPLIANCE, SCENARIO 1
ZCOMPLY4	ENGAGEMENT COMPLIANCE, SCENARIO 4
ZCONSL80	CONSOLE SETUP AT 80 SECONDS, SCENARIOS 1,2,3:(AVG)
ZCONSL110	CONSOLE SETUP AT 110 SECONDS, SCENARIOS 1,2,3:(AVG)
ZLNCH80	LAUNCHER SETUP AT 80 SECONDS, SCENARIOS 1,2,3:(AVG)

Table A.1—continued

VARIABLE	LABEL
ZLNCH110	LAUNCHER SETUP AT 110 SECONDS, SCENARIOS 1,2,3:(AVG)
ZIFFCO3	CODEBANK B CHANGE, SCENARIO 3
ZHFR4	HOLD FIRE, SCENARIO 4
ZSCFR4	CEASE FIRE, SCENARIO 4
ZAUT1	AUTONOMOUS, SCENARIO 1
ZFRND3	FRIENDLY PROTECT & ENABLE, SCENARIO 3
ZCONSOLA1	CONSOLE SETUP AT 80 SECONDS, SCENARIO 1
ZCONSOLB1	CONSOLE SETUP AT 110 SECONDS, SCENARIO 1
ZCONSOLA2	CONSOLE SETUP AT 80 SECONDS, SCENARIO 2
ZCONSOLB2	CONSOLE SETUP AT 110 SECONDS, SCENARIO 2
ZCONSOLA3	CONSOLE SETUP AT 80 SECONDS, SCENARIO 3
ZCONSOLB3	CONSOLE SETUP AT 110 SECONDS, SCENARIO 3
ZLNCHA1	LAUNCHER SETUP AT 80 SECONDS, SCENARIO 1
ZLNCHB1	LAUNCHER SETUP AT 110 SECONDS, SCENARIO 1
ZLNCHA2	LAUNCHER SETUP AT 80 SECONDS, SCENARIO 2
ZLNCHB2	LAUNCHER SETUP AT 110 SECONDS, SCENARIO 2
ZLNCH3	LAUNCHER SETUP, SCENARIO 3
ZMOF1RATE	ERROR TO ENGAGEMENT PERCENTAGE, METHOD OF FIRE, SCENARIO 1
ZMOF2RATE	ERROR TO ENGAGEMENT PERCENTAGE, METHOD OF FIRE, SCENARIO 2
ZMOF3RATE	ERROR TO ENGAGEMENT PERCENTAGE, METHOD OF FIRE, SCENARIO 3
ZMOF4RATE	ERROR TO ENGAGEMENT PERCENTAGE, METHOD OF FIRE, SCENARIO 4
ZMOF123	ERROR TO ENGAGEMENT PERCENTAGE, METHOD OF FIRE, SCENARIOS 1,2,3
ZTLL1RATE	ERROR TO ENGAGEMENT PERCENTAGE, TIME TO LAST LAUNCH, SCENARIO 1
ZTLL2RATE	ERROR TO ENGAGEMENT PERCENTAGE, TIME TO LAST LAUNCH, SCENARIO 2
ZTLL3RATE	ERROR TO ENGAGEMENT PERCENTAGE, TIME TO LAST LAUNCH, SCENARIO 3
ZTLL4RATE	ERROR TO ENGAGEMENT PERCENTAGE, TIME TO LAST LAUNCH, SCENARIO 4
ZTLL123	ERROR TO ENGAGEMENT PERCENTAGE, TIME TO LAST LAUNCH, SCENARIOS 1,2,3
ZFLT1RATE	ERROR TO ENGAGEMENT PERCENTAGE, FLIGHT DIRECTION, SCENARIO 1
ZFLT2RATE	ERROR TO ENGAGEMENT PERCENTAGE, FLIGHT DIRECTION, SCENARIO 2
ZATC3RATE	ERROR TO ENGAGEMENT PERCENTAGE, ASSET THREAT CODE, SCENARIO 3
ZATC4RATE	ERROR TO ENGAGEMENT PERCENTAGE, ASSET THREAT CODE, SCENARIO 4
ZSLO1RATE	ERROR TO ENGAGEMENT PERCENTAGE, SLOW SPEED TARGETS, SCENARIO 1
ZSLO2RATE	ERROR TO ENGAGEMENT PERCENTAGE, SLOW SPEED TARGETS, SCENARIO 2
ZSLO3RATE	ERROR TO ENGAGEMENT PERCENTAGE, SLOW SPEED TARGETS, SCENARIO 3
ZSLO4RATE	ERROR TO ENGAGEMENT PERCENTAGE, SLOW SPEED TARGETS, SCENARIO 4
ZSPC1RATE	ERROR TO ENGAGEMENT PERCENTAGE, SAFE PASSAGE CORRIDOR TARGETS, SCENARIO 1
ZSPC2RATE	ERROR TO ENGAGEMENT PERCENTAGE, SAFE PASSAGE CORRIDOR TARGETS, SCENARIO 2
ZSPC3RATE	ERROR TO ENGAGEMENT PERCENTAGE, SAFE PASSAGE CORRIDOR TARGETS, SCENARIO 3
ZSPC4RATE	ERROR TO ENGAGEMENT PERCENTAGE, SAFE PASSAGE CORRIDOR TARGETS, SCENARIO 4
DAMAGE	(Unstandardized) TOTAL DAMAGE, SCENARIOS 1,2,3
HIAW	(Unstandardized) TOTAL HOSTILE AIRCRAFT KILLED (IAW TACTICS) SCENARIOS 1,2,3
MSLCONS	(Unstandardized) MISSILES PER HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIOS 1,2,3
PTACPRO	SUMMARY MEASURE, BATTLEFIELD SURVIVAL
STACPRO	SUMMARY MEASURE, TACTICAL PROFICIENCY
TEKPROF	SUMMARY MEASURE, TECHNICAL PROFICIENCY

Table A.2
Summary Statistics

VARIABLE	LABEL	MEAN	STDDEV	MIN	MAX	N
AFQT_PER	AFQT PERCENTILE	63.95	19.51	10	99	294
OPERMON	TOTAL MONTHS AS OPERATOR	5.76	9.75	0	46	302
UNITMEM	AIT OR UNIT MEMBER (0,1)	0.69	0.46	0	1	315
TRAINDAY	TRAINING DAYS IN THE PREVIOUS 6 MONTHS	9.74	19.90	0	114	305
LOCATION	FRG LOCATION (0,1)	0.40	0.49	0	1	315
TDAMAINT	TDA/MAINT AS LAST OR CURRENT JOB (0,1)	0.05	0.23	0	1	315
DAMAGE1	TIMES AN ASSET WAS DAMAGED, SCENARIO 1	1.37	0.97	0	5	304
DAMAGE2	TIMES AN ASSET WAS DAMAGED, SCENARIO 2	4.39	1.79	0	9	310
DAMAGE3	TIMES AN ASSET WAS DAMAGED, SCENARIO 3	6.15	2.05	2	12	301
DAMAGE4	TIMES AN ASSET WAS DAMAGED, SCENARIO 4	14.98	3.96	5	23	296
ZDAMAGE1	(Standardized) ASSET PROTECTION, SCENARIO 1	-0.0	1.0	-3.7	1.4	304
ZDAMAGE2	(Standardized) ASSET PROTECTION, SCENARIO 2	0.0	1.0	-2.6	2.5	310
ZDAMAGE3	(Standardized) ASSET PROTECTION, SCENARIO 3	0.0	1.0	-2.9	2.0	301
ZDAMAGE4	(Standardized) ASSET PROTECTION, SCENARIO 4	-0.0	1.0	-2.0	2.5	296
DAM_A2	TIMES ASSET A DAMAGED, SCENARIO 2	1.51	1.06	0	4	310
DAM_B2	TIMES ASSET B DAMAGED, SCENARIO 2	2.88	1.25	0	6	310
DAM_A3	TIMES ASSET A DAMAGED, SCENARIO 3	1.41	0.66	0	3	301
DAM_D3	TIMES ASSET D DAMAGED, SCENARIO 3	0.65	0.77	0	3	301
DAM_E3	TIMES ASSET E DAMAGED, SCENARIO 3	4.09	1.28	1	7	301
DAM_A4	TIMES ASSET A DAMAGED, SCENARIO 4	1.80	0.73	0	3	296
DAM_B4	TIMES ASSET B DAMAGED, SCENARIO 4	1.51	0.62	0	2	296
DAM_C4	TIMES ASSET C DAMAGED, SCENARIO 4	2.18	1.00	0	4	296
DAM_D4	TIMES ASSET D DAMAGED, SCENARIO 4	4.74	1.76	0	8	296
DAM_E4	TIMES ASSET E DAMAGED, SCENARIO 4	4.75	0.97	1	6	296
ZDIFB2A2	ASSET PROTECTION BY ASSET PRIORITY, ASSETS A & B, SCENARIO 2	0.0	1.0	-2.3	3.1	310
ZDIFD3A3	ASSET PROTECTION BY ASSET PRIORITY, ASSETS A & D, SCENARIO 3	0.0	1.0	-2.7	3.3	301
ZDIFE3A3	ASSET PROTECTION BY ASSET PRIORITY, ASSETS A & E, SCENARIO 3	0.0	1.0	-3.0	2.7	301
ZDIFD3E3	ASSET PROTECTION BY ASSET PRIORITY, ASSETS D & E, SCENARIO 3	0.0	1.0	-2.8	2.7	301
HOKILL1	HOSTILE AIRCRAFT KILLED, SCENARIO 1	20.08	3.64	8	31	305
HOKILL2	HOSTILE AIRCRAFT KILLED, SCENARIO 2	27.75	2.72	18	32	308
HOKILL3	HOSTILE AIRCRAFT KILLED, SCENARIO 3	41.40	6.65	20	55	301
HOKILL4	HOSTILE AIRCRAFT KILLED, SCENARIO 4	37.07	8.33	4	59	295
HIAW1	HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIO 1	8.30	3.30	1	16	305
HIAW2	HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIO 2	17.13	3.83	3	25	308
HIAW3	HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIO 3	23.05	6.61	5	37	301

Table A.2—continued

VARIABLE	LABEL	MEAN	STDDEV	MIN	MAX	N
HIAW4	HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIO 4	11.03	4.73	0	21	295
ZHIAW1	(Standardized) HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIO 1	0.0	1.0	-2.2	2.3	305
ZHIAW2	(Standardized) HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIO 2	-0.0	1.0	-3.7	2.1	308
ZHIAW3	(Standardized) HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIO 3	0.0	1.0	-2.7	2.1	301
ZHIAW4	(Standardized) HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIO 4	-0.0	1.0	-2.3	2.1	295
FRKILL1	FRIENDLY AIRCRAFT KILLED, SCENARIO 1	0.02	0.17	0	2	305
FRKILL2	FRIENDLY AIRCRAFT KILLED, SCENARIO 2	0.66	0.65	0	4	310
FRKILL3	FRIENDLY AIRCRAFT KILLED, SCENARIO 3	0.59	0.79	0	4	301
FRKILL4	FRIENDLY AIRCRAFT KILLED, SCENARIO 4	0.03	0.29	0	4	296
MSLCONS1	MISSILES PER HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIO 1	3.33	2.28	1.25	16	300
MSLCONS2	MISSILES PER HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIO 2	1.85	0.50	1.23	4	304
MSLCONS3	MISSILES PER HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIO 3	2.19	0.74	1.27	6.1	296
MSLCONS4	MISSILES PER HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIO 4	6.20	5.95	1.93	32.5	289
ZMSLCON1	(Standardized) MISSILES PER HOSTILE AIRCRAFT KILLED, (IAW) TACTICS, SCENARIO 1	-0.0	1.0	-5.6	0.9	300
ZMSLCON2	(Standardized) MISSILES PER HOSTILE AIRCRAFT KILLED, (IAW) TACTICS, SCENARIO 2	-0.0	1.0	-4.3	1.3	304
ZMSLCON3	(Standardized) MISSILES PER HOSTILE AIRCRAFT KILLED, (IAW) TACTICS, SCENARIO 3	-0.0	1.0	-5.3	1.2	296
ZMSLCON4	(Standardized) MISSILES PER HOSTILE AIRCRAFT KILLED, (IAW) TACTICS, SCENARIO 4	-0.0	1.0	-4.4	0.7	289
IPERCOR	INITIALIZATION WRITTEN TEST, PERCENT CORRECT	50.5%	15.0%	20.0%	96.0%	314
ZIPERCOR	(Standardized) INITIALIZATION WRITTEN TEST, PERCENT CORRECT	0.0	1.0	-2.0	3.0	314
TPERCOR	TACTICAL SOP WRITTEN TEST, PERCENT CORRECT	53.2%	19.1%	4.0%	92.0%	218
ZTPERCOR	(Standardized) TACTICAL SOP WRITTEN TEST, PERCENT CORRECT	0.0	1.0	-2.6	2.0	218
NETER1	NETTED ERRORS, SCENARIO 1	3.32	2.81	0	12	305
ZNETER1	(Standardized) NETTED ERRORS, SCENARIO 1	-0.0	1.0	-3.1	1.2	305
MANUALID	MANUAL IDENTIFICATIONS, SCENARIO 3	31.0%	23.8%	0.0%	100.0%	301
ZMANALID	(Standardized) MANUAL IDENTIFICATIONS, SCENARIO 3	0.0	1.0	-1.3	2.9	301
COMPLY1	ENGAGEMENT COMPLIANCE, SCENARIO 1	61.7%	36.6%	0.0%	100.0%	306
ZCOMPLY1	(Standardized) ENGAGEMENT COMPLIANCE, SCENARIO 1	0.0	1.0	-1.7	1.0	306
COMPLY4	ENGAGEMENT COMPLIANCE, SCENARIO 4	47.7%	41.5%	0.0%	100.0%	278
CONSL80	CONSOLE SETUP AT 80 SECONDS, SCENARIOS 1,2,3:(AVG)	48.6%	33.5%	0.0%	100.0%	310

Table A.2—continued

VARIABLE	LABEL	MEAN	STDDEV	MIN	MAX	N
CONSL110	CONSOLE SETUP AT 110 SECONDS, SCENARIOS 1,2,3:(AVG)	64.5%	32.4%	0.0%	100.0%	310
ZCON110	(Standardized) CONSOLE SETUP AT 110 SECONDS, SCENARIOS 1,2,3:(AVG)	0.0	1.0	-2.0	1.1	310
LNCH80	LAUNCHER SETUP AT 80 SECONDS, SCENARIOS 1,2,3:(AVG)	76.0%	29.4%	0.0%	100.0%	310
LNCH110	LAUNCHER SETUP AT 110 SECONDS, SCENARIOS 1,2,3:(AVG)	77.5%	29.1%	0.0%	100.0%	310
ZLNCH110	(Standardized) LAUNCHER SETUP AT 110 SECONDS, SCENARIOS 1,2,3:(AVG)	-0.0	1.0	-2.7	0.8	310
IFFCO3	CODEBANK B CHANGE, SCENARIO 3:(0,100%)	50.8%	50.1%	0.0%	100.0%	299
ZIFFCO3	(Standardized) CODEBANK B CHANGE, SCENARIO 3	0.0	1.0	-1.0	1.0	299
HFR4	HOLD FIRE, SCENARIO 4:(0,100%)	85.5%	35.3%	0.0%	100.0%	193
SCFR4	CEASE FIRE, SCENARIO 4:(0,100%)	78.4%	41.3%	0.0%	100.0%	291
AUT1	GOING AUTONOMOUS, SCENARIO 1:(0,100%)	87.1%	33.6%	0.0%	100.0%	225
FRND3	FRIENDLY PROTECT & ENABLE, SCENARIO 3:(0,100%)	87.6%	33.0%	0.0%	100.0%	299
CONSOLA1	CONSOLE SETUP AT 80 SECONDS, SCENARIO 1:(0,100%)	13.8%	34.5%	0.0%	100.0%	225
CONSOLB1	CONSOLE SETUP AT 110 SECONDS, SCENARIO 1:(0,100%)	30.7%	46.2%	0.0%	100.0%	225
CONSOLA2	CONSOLE SETUP AT 80 SECONDS, SCENARIO 2:(0,100%)	53.9%	49.9%	0.0%	100.0%	304
CONSOLB2	CONSOLE SETUP AT 110 SECONDS, SCENARIO 2:(0,100%)	69.4%	46.2%	0.0%	100.0%	304
CONSOLA3	CONSOLE SETUP AT 80 SECONDS, SCENARIO 3:(0,100%)	66.2%	47.4%	0.0%	100.0%	299
CONSOLB3	CONSOLE SETUP AT 110 SECONDS, SCENARIO 3:(0,100%)	82.3%	38.3%	0.0%	100.0%	299
LNCHA1	LAUNCHER SETUP AT 80 SECONDS, SCENARIO 1:(0,100%)	62.2%	48.6%	0.0%	100.0%	225
LNCHB1	LAUNCHER SETUP AT 110 SECONDS, SCENARIO 1:(0,100%)	64.9%	47.8%	0.0%	100.0%	225
LNCHA2	LAUNCHER SETUP AT 80 SECONDS, SCENARIO 2:(0,100%)	86.8%	33.9%	0.0%	100.0%	304
LNCHB2	LAUNCHER SETUP AT 110 SECONDS, SCENARIO 2:(0,100%)	88.8%	31.6%	0.0%	100.0%	304
LNCH3	LAUNCHER SETUP, SCENARIO 3:(0,100%)	73.6%	44.2%	0.0%	100.0%	299
MOF1RATE	ERROR TO ENGAGEMENT PERCENTAGE, METHOD OF FIRE, SCENARIO 1	26.4%	11.3%	0.0%	68.8%	305
MOF2RATE	ERROR TO ENGAGEMENT PERCENTAGE, METHOD OF FIRE, SCENARIO 2	16.9%	7.8%	3.1%	47.1%	310
MOF3RATE	ERROR TO ENGAGEMENT PERCENTAGE, METHOD OF FIRE, SCENARIO 3	14.7%	7.6%	2.1%	44.8%	300
MOF4RATE	ERROR TO ENGAGEMENT PERCENTAGE, METHOD OF FIRE, SCENARIO 4	14.3%	6.8%	0.0%	40.0%	294
MOF123	ERROR TO ENGAGEMENT PERCENTAGE, METHOD OF FIRE, SCENARIOS 1,2,3	19.3%	6.5%	5.9%	46.2%	313
ZMOF123	(Standardized) ERROR TO ENGAGEMENT PERCENTAGE, METHOD OF FIRE, SCENARIOS 1,2,3	-0.00	1.00	-4.11	2.03	314
TLL1RATE	ERROR TO ENGAGEMENT PERCENTAGE, TIME TO LAST LAUNCH, SCENARIO 1	20.8%	18.9%	0.0%	69.6%	305
TLL2RATE	ERROR TO ENGAGEMENT PERCENTAGE, TIME TO LAST LAUNCH, SCENARIO 2	11.1%	11.2%	0.0%	54.8%	310

Table A.2—continued

VARIABLE	LABEL	MEAN	STDDEV	MIN	MAX	N
TLL3RATE	ERROR TO ENGAGEMENT PERCENTAGE, TIME TO LAST LAUNCH, SCENARIO 3	11.7%	10.5%	0.0%	54.1%	300
TLL4RATE	ERROR TO ENGAGEMENT PERCENTAGE, TIME TO LAST LAUNCH, SCENARIO 4	25.1%	23.0%	0.0%	89.1%	296
TLL123	ERROR TO ENGAGEMENT PERCENTAGE, TIME TO LAST LAUNCH, SCENARIOS 1,2,3	14.6%	11.4%	0.0%	51.5%	314
ZTLL123	(Standardized) ERROR TO ENGAGEMENT PERCENTAGE, TIME TO LAST LAUNCH, SCENARIOS 1,2,3	-0.00	1.00	-3.26	1.29	314
FLT1RATE	ERROR TO ENGAGEMENT PERCENTAGE, FLIGHT DIRECTION, SCENARIO 1	2.9%	4.9%	0.0%	22.2%	304
FLT2RATE	ERROR TO ENGAGEMENT PERCENTAGE, FLIGHT DIRECTION, SCENARIO 2	7.1%	4.9%	0.0%	26.1%	309
ATC3RATE	ERROR TO ENGAGEMENT PERCENTAGE, ASSET THREAT CODE, SCENARIO 3	19.7%	14.7%	0.0%	63.3%	301
ATC4RATE	ERROR TO ENGAGEMENT PERCENTAGE, ASSET THREAT CODE, SCENARIO 4	34.8%	24.7%	0.0%	91.3%	296
ZATC3RAT	(Standardized) ERROR TO ENGAGEMENT PERCENTAGE, ASSET THREAT CODE, SCENARIO 3	0.0	1.0	-3.0	1.3	301
SLO1RATE	ERROR TO ENGAGEMENT PERCENTAGE, SLOW SPEED TARGETS, SCENARIO 1	0.0%	0.4%	0.0%	4.0%	305
SLO2RATE	ERROR TO ENGAGEMENT PERCENTAGE, SLOW SPEED TARGETS, SCENARIO 2	0.0%	0.2%	0.0%	3.2%	310
SLO3RATE	ERROR TO ENGAGEMENT PERCENTAGE, SLOW SPEED TARGETS, SCENARIO 3	0.1%	0.5%	0.0%	3.7%	301
SLO4RATE	ERROR TO ENGAGEMENT PERCENTAGE, SLOW SPEED TARGETS, SCENARIO 4	0.0%	0.2%	0.0%	1.9%	296
SPC1RATE	ERROR TO ENGAGEMENT PERCENTAGE, SAFE PASSAGE CORRIDOR TARGETS, SCENARIO 1	0.2%	0.9%	0.0%	5.3%	305
SPC2RATE	ERROR TO ENGAGEMENT PERCENTAGE, SAFE PASSAGE CORRIDOR TARGETS, SCENARIO 2	0.0%	0.0%	0.0%	0.0%	310
SPC3RATE	ERROR TO ENGAGEMENT PERCENTAGE, SAFE PASSAGE CORRIDOR TARGETS, SCENARIO 3	1.6%	1.9%	0.0%	7.1%	301
SPC4RATE	ERROR TO ENGAGEMENT PERCENTAGE, SAFE PASSAGE CORRIDOR TARGETS, SCENARIO 4	11.8%	4.8%	0.0%	40.0%	295
DAMAGE	TOTAL DAMAGE, SCENARIOS 1,2,3	12.0	3.6	4	24	291
HIAW	TOTAL HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIOS 1,2,3	48.5	11.2	13	72	291
MSLCONS	MISSILES PER HOSTILE AIRCRAFT KILLED (IAW TACTICS), SCENARIOS 1,2,3	2.2	0.6	1.4	5.4	311
PTACPRO	SUMMARY MEASURE, BATTLEFIELD SURVIVAL	-0.0	1.0	-3.1	2.0	314
STACPRO	SUMMARY MEASURE, TACTICAL PROFICIENCY	0.0	1.0	-2.9	2.0	314
TEKPROF	SUMMARY MEASURE, TECHNICAL PROFICIENCY	0.0	1.0	-3.0	2.3	315

Table A.3

Correlation Coefficients

PEARSON CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0 / NUMBER OF OBSERVATIONS

	AFQT_PER	OPERMON	UNITMEM	TRAINDAY	LOCFRG	ZDAMAGE1	ZDAMAGE2	ZDAMAGE3	ZDAMAGE4
AFQT_PER	1.0000 0.00 294	0.0428 0.47 282	-0.0223 0.70 294	-0.0291 0.62 284	-0.0367 0.53 294	0.1645 0.01 283	0.2425 0.00 290	0.2254 0.00 282	0.0603 0.32 277
OPERMON	0.0428 0.47 282	1.0000 0.00 302	0.4073 0.00 302	0.5069 0.00 296	0.3810 0.00 302	0.1281 0.03 292	0.2350 0.00 297	0.2432 0.00 288	0.1157 0.05 283
UNITMEM	-0.0223 0.70 294	0.4073 0.00 302	1.0000 0.00 315	0.3350 0.00 305	0.5446 0.00 315	0.1074 0.06 304	0.1394 0.01 310	0.0638 0.27 301	0.0226 0.70 296
TRAINDAY	-0.0291 0.62 284	0.5069 0.00 296	0.3350 0.00 305	1.0000 0.00 305	0.2083 0.00 305	0.1221 0.04 295	0.1492 0.01 300	0.2162 0.00 291	0.0507 0.39 287
LOCFRG	-0.0367 0.53 294	0.3810 0.00 302	0.5446 0.00 315	0.2083 0.00 305	1.0000 0.00 315	0.0601 0.30 304	0.1369 0.02 310	0.1009 0.08 301	0.1740 0.00 2[illegible]
ZDAMAGE1	0.1645 0.01 283	0.1281 0.03 292	0.1074 0.06 304	0.1221 0.04 295	0.0601 0.30 304	1.0000 0.00 304	0.2449 0.00 300	0.2056 0.00 291	0.0196 0.74 286
ZDAMAGE2	0.2425 0.00 290	0.2350 0.00 297	0.1394 0.01 310	0.1492 0.01 300	0.1369 0.02 310	0.2449 0.00 300	1.0000 0.00 310	0.3131 0.00 299	0.1132 0.05 293
ZDAMAGE3	0.2254 0.00 282	0.2432 0.00 288	0.0638 0.27 301	0.2162 0.00 291	0.1009 0.08 301	0.2056 0.00 291	0.3131 0.00 299	1.0000 0.00 301	0.2457 0.00 286
ZDAMAGE4	0.0603 0.32 277	0.1157 0.05 283	0.0226 0.70 296	0.0507 0.39 287	0.1740 0.00 296	0.0196 0.74 286	0.1132 0.05 293	0.2457 0.00 286	1.0000 0.00 296
ZHAW1	0.1667 0.00 284	0.2437 0.00 293	0.2343 0.00 305	0.2466 0.00 296	0.1437 0.01 305	0.1535 0.01 304	0.2815 0.00 301	0.2800 0.00 292	-0.0102 0.86 287
ZHAW2	0.1721 0.00 288	0.1274 0.03 295	0.2557 0.00 308	0.0488 0.40 298	0.1296 0.02 308	0.0825 0.16 298	0.3188 0.00 308	0.1006 0.08 297	-0.1073 0.07 291
ZHAW3	0.2300 0.00 282	0.2160 0.00 288	0.1854 0.00 301	0.2184 0.00 291	0.1001 0.08 301	0.0774 0.19 291	0.2876 0.00 299	0.3122 0.00 301	-0.0671 0.26 286
ZHAW4	0.1725 0.00 276	0.1114 0.06 282	0.1405 0.02 295	0.0646 0.28 286	-0.0264 0.65 295	0.0793 0.18 285	0.2298 0.00 292	0.0375 0.53 285	-0.4141 0.00 295
ZIPERCOR	0.2809 0.00 293	0.5602 0.00 301	0.3284 0.00 314	0.3973 0.00 304	0.3613 0.00 314	0.2076 0.00 303	0.3168 0.00 309	0.3071 0.00 300	0.1572 0.01 295
ZTPERCOR	0.1934 0.01 204	0.5774 0.00 205	0.0000 1.00 218	0.3092 0.00 208	0.1606 0.02 218	0.0990 0.15 213	0.2628 0.00 217	0.2691 0.00 213	0.0597 0.39 206
ZMSLCON1	0.1541 0.01 279	0.1740 0.00 289	0.1691 0.00 300	0.1752 0.00 292	0.0962 0.10 300	-0.0072 0.90 299	0.2010 0.00 296	0.1773 0.00 288	-0.0281 0.64 282
ZMSLCON2	0.1146 0.05 284	0.0313 0.60 291	0.1622 0.00 304	-0.0612 0.30 294	0.0389 0.50 304	0.0930 0.11 295	0.1834 0.00 304	0.0368 0.53 293	-0.1040 0.08 287
ZMSLCON3	0.1314 0.03 277	0.0865 0.15 284	0.1685 0.00 296	0.0972 0.10 286	0.0326 0.58 296	-0.0223 0.71 286	0.0892 0.13 294	-0.0900 0.12 296	-0.2584 0.00 281
ZMSLCON4	0.0100 0.87 270	0.0146 0.81 276	0.0668 0.26 289	0.0205 0.73 280	-0.1018 0.08 289	0.0021 0.97 279	0.0506 0.39 286	-0.1021 0.09 279	-0.6253 0.00 289

Table A.3—continued

PEARSON CORRELATION COEFFICIENTS / PROB > |R| UNDER H0: RHO=0 / NUMBER OF OBSERVATIONS

	AFQT_PER	OPERMON	UNITMEM	TRAINDAY	LOCPRO	ZDAMAGE1	ZDAMAGE2	ZDAMAGE3	ZDAMAGE4
PTACPRO	0.2790 0.00 293	0.2810 0.00 301	0.2671 0.00 314	0.2358 0.00 304	0.1542 0.01 314	0.3188 0.00 304	0.5376 0.00 310	0.4168 0.00 301	-0.0338 0.56 295
STACPRO	0.2241 0.00 293	0.2409 0.00 301	0.2445 0.00 314	0.1968 0.00 304	0.1004 0.08 314	0.0857 0.14 304	0.2991 0.00 310	0.2277 0.00 301	-0.1317 0.02 295
TEKPROF	0.2681 0.00 294	0.3602 0.00 302	0.2306 0.00 315	0.2334 0.00 305	0.2714 0.00 315	0.2210 0.00 304	0.3524 0.00 310	0.2501 0.00 301	0.0360 0.54 296
ZNETER1	0.0883 0.14 284	0.2501 0.00 293	0.2009 0.00 305	0.1701 0.00 296	0.1808 0.00 305	-0.1135 0.05 303	0.0830 0.15 301	0.0805 0.17 292	-0.0583 0.32 287
ZMANALID	0.1410 0.02 282	0.0809 0.17 288	-0.0642 0.27 301	0.0855 0.15 291	-0.1269 0.03 301	0.1201 0.04 291	0.1408 0.01 299	0.4916 0.00 301	0.0866 0.14 286
ZCOMPLY1	0.1091 0.07 285	0.2861 0.00 294	0.2531 0.00 306	0.2611 0.00 297	0.1843 0.00 306	0.3578 0.00 304	0.2788 0.00 302	0.2582 0.00 293	0.1031 0.08 288
ZIPPCO3	0.1911 0.00 280	0.4155 0.00 286	0.2669 0.00 299	0.2352 0.00 290	0.2303 0.00 299	0.1581 0.01 289	0.3262 0.00 297	0.2845 0.00 297	0.1231 0.04 284
ZCON110	0.1091 0.06 290	0.1986 0.00 297	0.1268 0.03 310	0.0988 0.09 301	0.1307 0.02 310	0.0732 0.21 300	0.1602 0.01 306	0.1556 0.01 298	-0.0120 0.84 292
ZLNCH110	0.2085 0.00 290	0.0162 0.78 297	0.0102 0.86 310	0.0553 0.34 301	-0.0004 0.99 310	0.0423 0.47 300	0.1704 0.00 306	0.0404 0.49 298	-0.0332 0.57 292
ZATC3RAT	0.0156 0.79 282	0.0604 0.31 288	0.1966 0.00 301	0.0881 0.13 291	0.0460 0.43 301	-0.0698 0.24 291	-0.0099 0.87 299	-0.2665 0.00 301	-0.2952 0.00 286
ZMOP123	0.2128 0.00 293	0.1714 0.00 301	0.0818 0.15 314	0.0915 0.11 304	0.0866 0.13 314	0.2340 0.00 304	0.3071 0.00 310	0.3551 0.00 301	0.1419 0.01 295
ZTLL123	0.1172 0.05 293	0.1274 0.03 301	0.2452 0.00 314	0.1368 0.02 304	0.0711 0.21 314	-0.0371 0.52 304	0.1492 0.01 310	0.0122 0.83 301	-0.2266 0.00 295

Table A.3—continued

PEARSON CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0 / NUMBER OF OBSERVATIONS

	ZHIAW1	ZHIAW2	ZHIAW3	ZHIAW4	ZIPERCOR	ZTPERCOR	ZMSLCON1	ZMSLCON2	ZMSLCON3
AFQT_PER	0.1667	0.1721	0.2300	0.1725	0.2809	0.1934	0.1541	0.1146	0.1314
	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.05	0.03
	284	288	282	276	293	204	279	284	277
OFFRMON	0.2437	0.1274	0.2160	0.1114	0.5602	0.5774	0.1740	0.0313	0.0865
	0.00	0.03	0.00	0.06	0.00	0.00	0.00	0.60	0.15
	293	295	288	282	301	205	289	291	284
UNITMEM	0.2343	0.2557	0.1854	0.1405	0.3284	0.0000	0.1691	0.1622	0.1685
	0.00	0.00	0.00	0.02	0.00	1.00	0.00	0.00	0.00
	305	308	301	295	314	218	300	304	296
TRAINDAY	0.2466	0.0488	0.2184	0.0646	0.3973	0.3092	0.1752	-0.0612	0.0972
	0.00	0.40	0.00	0.28	0.00	0.00	0.00	0.30	0.10
	296	298	291	286	304	208	292	294	286
LOCPRO	0.1437	0.1296	0.1001	-0.0264	0.3613	0.1606	0.0962	0.0389	0.0326
	0.01	0.02	0.08	0.65	0.00	0.02	0.10	0.50	0.58
	305	308	301	295	314	218	300	304	296
ZDAMAGE1	0.1535	0.0825	0.0774	0.0793	0.2076	0.0990	-0.0072	0.0930	-0.0223
	0.01	0.16	0.19	0.18	0.00	0.15	0.90	0.11	0.71
	304	298	291	285	303	213	299	295	286
ZDAMAGE2	0.2815	0.3188	0.2876	0.2298	0.3168	0.2628	0.2010	0.1834	0.0892
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13
	301	308	299	292	309	217	296	304	294
ZDAMAGE3	0.2800	0.1006	0.3122	0.0375	0.3071	0.2691	0.1773	0.0368	-0.0900
	0.00	0.08	0.00	0.53	0.00	0.00	0.00	0.53	0.12
	292	297	301	285	300	213	288	293	296
ZDAMAGE4	-0.0102	-0.1073	-0.0671	-0.4141	0.1572	0.0597	-0.0281	-0.1040	-0.2584
	0.86	0.07	0.26	0.00	0.01	0.39	0.64	0.08	0.00
	287	291	286	295	295	206	282	287	281
ZHIAW1	1.0000	0.4402	0.4662	0.2736	0.3886	0.2463	0.8007	0.3561	0.3367
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	305	299	292	286	304	214	300	296	287
ZHIAW2	0.4402	1.0000	0.4520	0.3426	0.2266	0.0753	0.3666	0.9091	0.4209
	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00
	299	308	297	290	307	216	294	304	292
ZHIAW3	0.4662	0.4520	1.0000	0.4712	0.3459	0.2998	0.3893	0.3520	0.7568
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	292	297	301	285	300	213	288	293	296
ZHIAW4	0.2736	0.3426	0.4712	1.0000	0.2015	0.1315	0.2863	0.2675	0.3940
	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00
	286	290	285	295	294	205	281	286	280
ZIPERCOR	0.3886	0.2266	0.3459	0.2015	1.0000	0.4965	0.2978	0.1440	0.1446
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
	304	307	300	294	314	218	299	303	295
ZTPERCOR	0.2463	0.0753	0.2998	0.1315	0.4965	1.0000	0.2120	-0.0006	0.1650
	0.00	0.27	0.00	0.06	0.00	0.00	0.00	0.99	0.02
	214	216	213	205	218	218	211	215	209
ZMSLCON1	0.8007	0.3666	0.3893	0.2863	0.2978	0.2120	1.0000	0.2821	0.3051
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	300	294	288	281	299	211	300	291	283
ZMSLCON2	0.3561	0.9091	0.3520	0.2675	0.1440	-0.0006	0.2821	1.0000	0.3833
	0.00	0.00	0.00	0.00	0.01	0.99	0.00	0.00	0.00
	296	304	293	286	303	215	291	304	289
ZMSLCON3	0.3367	0.4209	0.7568	0.3940	0.1446	0.1650	0.3051	0.3833	1.0000
	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00
	287	292	296	280	295	209	283	289	296
ZMSLCON4	0.2432	0.2747	0.2729	0.7679	0.0125	0.0133	0.2408	0.2472	0.2867
	0.00	0.00	0.00	0.00	0.83	0.85	0.00	0.00	0.00
	280	284	279	289	288	203	275	282	274

Table A.3—continued

PEARSON CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0 / NUMBER OF OBSERVATIONS

	ZHIAW1	ZHIAW2	ZHIAW3	ZHIAW4	ZIPERCOR	ZTPERCOR	ZMSLCON1	ZMSLCON2	ZMSLCON3
PTACPRO	0.7617 0.00 305	0.7502 0.00 308	0.7661 0.00 301	0.4383 0.00 294	0.4493 0.00 313	0.2919 0.00 218	0.6126 0.00 300	0.6379 0.00 304	0.5798 0.00 296
STACPRO	0.7062 0.00 305	0.6803 0.00 308	0.7309 0.00 301	0.4245 0.00 294	0.3456 0.00 313	0.2445 0.00 218	0.6189 0.00 300	0.6135 0.00 304	0.6437 0.00 296
TSKPROF	0.3304 0.00 305	0.2769 0.00 308	0.3864 0.00 301	0.2374 0.00 295	0.5552 0.00 314	0.3790 0.00 218	0.3132 0.00 300	0.2059 0.00 304	0.2051 0.00 296
ZNETER1	0.4411 0.00 304	0.2116 0.00 299	0.3196 0.00 292	0.1810 0.00 286	0.2372 0.00 304	0.2466 0.00 214	0.5466 0.00 299	0.1289 0.03 296	0.2749 0.00 287
ZMANALID	0.1016 0.08 292	-0.0453 0.44 297	0.0528 0.36 301	-0.0187 0.75 285	0.0724 0.21 300	-0.0046 0.95 213	0.0919 0.12 288	-0.0067 0.91 293	-0.1748 0.00 296
ZCOMPLY1	0.4545 0.00 305	0.1860 0.00 300	0.2525 0.00 293	0.0990 0.09 287	0.3885 0.00 305	0.3320 0.00 215	0.3442 0.00 300	0.1595 0.01 297	0.1541 0.01 288
ZIPPCO3	0.2789 0.00 290	0.2281 0.00 295	0.2528 0.00 297	0.0876 0.14 283	0.4353 0.00 298	0.3853 0.00 210	0.1554 0.01 285	0.1984 0.00 291	0.0839 0.15 292
ZCON110	0.1653 0.00 301	0.1488 0.01 304	0.2124 0.00 298	0.1363 0.02 291	0.2589 0.00 309	0.1529 0.03 214	0.1756 0.00 296	0.0783 0.18 300	0.1320 0.02 293
ZLNCH110	0.1378 0.02 301	0.1717 0.00 304	0.2795 0.00 298	0.2006 0.00 291	0.1590 0.01 309	0.1120 0.10 214	0.1682 0.00 296	0.1171 0.04 300	0.1887 0.00 293
ZATC3RAT	0.2963 0.00 292	0.3931 0.00 297	0.6427 0.00 301	0.4628 0.00 285	0.1159 0.04 300	0.0844 0.22 213	0.2933 0.00 288	0.4117 0.00 293	0.8180 0.00 296
ZMOF123	0.3390 0.00 305	0.3305 0.00 308	0.3038 0.00 301	0.0456 0.44 294	0.2217 0.00 313	0.2058 0.00 218	0.0722 0.21 300	0.2341 0.00 304	0.0898 0.12 296
ZTLL123	0.6554 0.00 305	0.6110 0.00 308	0.5754 0.00 301	0.4322 0.00 294	0.2571 0.00 313	0.1333 0.05 218	0.6839 0.00 300	0.5931 0.00 304	0.6338 0.00 296

Table A.3—continued

PEARSON CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0 / NUMBER OF OBSERVATIONS

	ZMSLCON4	PTACPRO	STACPRO	TEKPROF	ZNETER1	ZMANALID	ZCOMPLY1	ZIFFCO3	ZCON110
APQT_PER	0.0100	0.2790	0.2241	0.2681	0.0883	0.1410	0.1091	0.1911	0.1091
	0.87	0.00	0.00	0.00	0.14	0.02	0.07	0.00	0.06
	270	293	293	294	284	282	285	280	290
OPERMON	-0.0146	0.2810	0.2409	0.3602	0.2501	0.0809	0.2861	0.4155	0.1986
	0.81	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00
	276	301	301	302	293	288	294	286	297
UNITMEM	0.0668	0.2671	0.2445	0.2306	0.2009	-0.0642	0.2531	0.2669	0.1268
	0.26	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.03
	289	314	314	315	305	301	306	299	310
TRAINDAY	0.0205	0.2358	0.1968	0.2334	0.1701	0.0855	0.2611	0.2352	0.0988
	0.73	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.09
	280	304	304	305	296	291	297	290	301
LOCPRO	-0.1018	0.1542	0.1004	0.2714	0.1808	-0.1269	0.1843	0.2303	0.1307
	0.08	0.01	0.08	0.00	0.00	0.03	0.00	0.00	0.02
	289	314	314	315	305	301	306	299	310
ZDAMAGE1	0.0021	0.3188	0.0857	0.2210	-0.1135	0.1201	0.3578	0.1581	0.0732
	0.97	0.00	0.14	0.00	0.05	0.04	0.00	0.01	0.21
	279	304	304	304	303	291	304	289	300
ZDAMAGE2	0.0506	0.5376	0.2991	0.3524	0.0830	0.1408	0.2788	0.3262	0.1602
	0.39	0.00	0.00	0.00	0.15	0.01	0.00	0.00	0.01
	286	310	310	310	301	299	302	297	306
ZDAMAGE3	-0.1021	0.4168	0.2277	0.2501	0.0805	0.4916	0.2582	0.2845	0.1556
	0.09	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.01
	279	301	301	301	292	301	293	297	298
ZDAMAGE4	-0.6253	-0.0338	-0.1317	0.0360	-0.0583	0.0866	0.1031	0.1231	-0.0120
	0.00	0.56	0.02	0.54	0.32	0.14	0.08	0.04	0.84
	289	295	295	296	287	286	288	284	292
ZHIAW1	0.2432	0.7617	0.7062	0.3304	0.4411	0.1016	0.4545	0.2789	0.1653
	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00
	280	305	305	305	304	292	305	290	301
ZHIAW2	0.2747	0.7502	0.6803	0.2769	0.2116	-0.0453	0.1860	0.2281	0.1488
	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.01
	284	308	308	308	299	297	300	295	304
ZHIAW3	0.2729	0.7661	0.7309	0.3864	0.3196	0.0528	0.2525	0.2528	0.2124
	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00
	279	301	301	301	292	301	293	297	298
ZHIAW4	0.7679	0.4383	0.4245	0.2374	0.1810	-0.0187	0.0990	0.0876	0.1363
	0.00	0.00	0.00	0.00	0.00	0.75	0.09	0.14	0.02
	289	294	294	295	286	285	287	283	291
ZIPERCOR	0.0125	0.4493	0.3456	0.5552	0.2372	0.0724	0.3885	0.4353	0.2589
	0.83	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00
	288	313	313	314	304	300	305	298	309
ZTPERCOR	0.0133	0.2919	0.2445	0.3790	0.2466	-0.0046	0.3320	0.3853	0.1529
	0.85	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.03
	203	218	218	218	214	213	215	210	214
ZMSLCON1	0.2408	0.6126	0.6189	0.3132	0.5466	0.0919	0.3442	0.1554	0.1756
	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.01	0.00
	275	300	300	300	299	288	300	285	296
ZMSLCON2	0.2472	0.6379	0.6135	0.2059	0.1289	-0.0067	0.1595	0.1984	0.0783
	0.00	0.00	0.00	0.00	0.03	0.91	0.01	0.00	0.18
	282	304	304	304	296	293	297	291	300
ZMSLCON3	0.2867	0.5798	0.6437	0.2051	0.2749	-0.1748	0.1541	0.0839	0.1320
	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.15	0.02
	274	296	296	296	287	296	288	292	293
ZMSLCON4	1.0000	0.2797	0.3266	0.1025	0.1743	-0.0767	0.0251	0.0466	0.0523
	0.00	0.00	0.00	0.08	0.00	0.20	0.68	0.44	0.38
	289	288	288	289	280	279	281	277	285

Table A.3—continued

PEARSON CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0 / NUMBER OF OBSERVATIONS

	ZMSLCON4	PTACPRO	STACPRO	TEKPROF	ZNETER1	ZMANALID	ZCOMPLY1	ZIPPCO3	ZCON110
PTACPRO	0.2797 0.00 288	1.0000 0.00 314	0.8596 0.00 314	0.4654 0.00 314	0.3632 0.00 305	0.1418 0.01 301	0.4710 0.00 306	0.3666 0.00 299	0.2249 0.00 310
STACPRO	0.3266 0.00 288	0.8596 0.00 314	1.0000 0.00 314	0.3492 0.00 314	0.5556 0.00 305	0.1728 0.00 301	0.4128 0.00 306	0.2767 0.00 299	0.1351 0.02 310
TEKPROF	0.1025 0.08 289	0.4654 0.00 314	0.3492 0.00 314	1.0000 0.00 315	0.1753 0.00 305	0.0077 0.89 301	0.3876 0.00 306	0.4265 0.00 299	0.6842 0.00 310
ZNETER1	0.1743 0.00 280	0.3632 0.00 305	0.5556 0.00 305	0.1753 0.00 305	1.0000 0.00 305	-0.0393 0.50 292	0.2591 0.00 305	0.0510 0.39 290	0.0594 0.30 301
ZMANALID	-0.0767 0.20 279	0.1418 0.01 301	0.1728 0.00 301	0.0077 0.89 301	-0.0393 0.50 292	1.0000 0.00 301	0.1693 0.00 293	0.1087 0.06 297	-0.0313 0.59 298
ZCOMPLY1	0.0251 0.68 281	0.4710 0.00 306	0.4128 0.00 306	0.3876 0.00 306	0.2591 0.00 305	0.1693 0.00 293	1.0000 0.00 306	0.3152 0.00 291	0.0729 0.21 302
ZIPPCO3	0.0466 0.44 277	0.3666 0.00 299	0.2767 0.00 299	0.4265 0.00 299	0.0510 0.39 290	0.1087 0.06 297	0.3152 0.00 291	1.0000 0.00 299	0.1586 0.01 299
ZCON110	0.0523 0.38 285	0.2249 0.00 310	0.1351 0.02 310	0.6842 0.00 310	0.0594 0.30 301	-0.0313 0.59 298	0.0729 0.21 302	0.1586 0.01 299	1.0000 0.00 310
ZLNCH110	0.1206 0.04 285	0.2314 0.00 310	0.2134 0.00 310	0.5710 0.00 310	0.0696 0.23 301	-0.0618 0.29 298	0.0567 0.33 302	0.0229 0.69 299	0.1485 0.01 310
ZATC3RAT	0.3989 0.00 279	0.4700 0.00 301	0.6132 0.00 301	0.1706 0.00 301	0.2663 0.00 292	-0.2315 0.00 301	0.0962 0.10 293	0.0515 0.38 297	0.0567 0.33 298
ZMOPI23	-0.0792 0.18 288	0.4408 0.00 314	0.4376 0.00 314	0.1677 0.00 314	0.0106 0.85 305	0.1314 0.02 301	0.3019 0.00 306	0.2390 0.00 299	0.1246 0.03 310
ZTLL123	0.4333 0.00 288	0.6931 0.00 314	0.8020 0.00 314	0.3187 0.00 314	0.4995 0.00 305	-0.0723 0.21 301	0.2927 0.00 306	0.1914 0.00 299	0.1214 0.03 310

Table A.3—continued

PEARSON CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0 / NUMBER OF OBSERVATIONS

	ZLNCH110	ZATC3RAT	ZMOP123	ZTLL123
APQT_PER	0.2085	0.0156	0.2128	0.1172
	0.00	0.79	0.00	0.05
	290	282	293	293
OPERMON	0.0162	0.0604	0.1714	0.1274
	0.78	0.31	0.00	0.03
	297	288	301	301
UNITMEM	0.0102	0.1966	0.0818	0.2452
	0.86	0.00	0.15	0.00
	310	301	314	314
TRAINDAY	0.0553	0.0881	0.0915	0.1368
	0.34	0.13	0.11	0.02
	301	291	304	304
LOCPRG	-0.0004	0.0460	0.0866	0.0711
	0.99	0.43	0.13	0.21
	310	301	314	314
ZDAMAGE1	0.0423	-0.0698	0.2340	-0.0371
	0.47	0.24	0.00	0.52
	300	291	304	304
ZDAMAGE2	0.1704	-0.0099	0.3071	0.1492
	0.00	0.87	0.00	0.01
	306	299	310	310
ZDAMAGE3	0.0404	-0.2665	0.3551	0.0122
	0.49	0.00	0.00	0.83
	298	301	301	301
ZDAMAGE4	-0.0332	-0.2952	0.1419	-0.2266
	0.57	0.00	0.01	0.00
	292	286	295	295
ZHIAW1	0.1378	0.2963	0.3390	0.6554
	0.02	0.00	0.00	0.00
	301	292	305	305
ZHIAW2	0.1717	0.3931	0.3305	0.6110
	0.00	0.00	0.00	0.00
	304	297	308	308
ZHIAW3	0.2795	0.6427	0.3038	0.5754
	0.00	0.00	0.00	0.00
	298	301	301	301
ZHIAW4	0.2006	0.4628	0.0456	0.4322
	0.00	0.00	0.44	0.00
	291	285	294	294
ZIPERCOR	0.1590	0.1159	0.2217	0.2571
	0.01	0.04	0.00	0.00
	309	300	313	313
ZTPERCOR	0.1120	0.0844	0.2058	0.1333
	0.10	0.22	0.00	0.05
	214	213	218	218
ZMSLCON1	0.1682	0.2933	0.0722	0.6839
	0.00	0.00	0.21	0.00
	296	288	300	300
ZMSLCON2	0.1171	0.4117	0.2341	0.5931
	0.04	0.00	0.00	0.00
	300	293	304	304
ZMSLCON3	0.1887	0.8180	0.0898	0.6338
	0.00	0.00	0.12	0.00
	293	296	296	296
ZMSLCON4	0.1206	0.3989	-0.0792	0.4333
	0.04	0.00	0.18	0.00
	285	279	288	288

Table A.3—continued

PEARSON CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0 / NUMBER OF OBSERVATIONS

	ZLNCH110	ZATC3RAT	ZMOP123	ZTLL123
PTACPRO	0.2314	0.4700	0.4408	0.6931
	0.00	0.00	0.00	0.00
	310	301	314	314
STACPRO	0.2134	0.6132	0.4376	0.8020
	0.00	0.00	0.00	0.00
	310	301	314	314
TEKPROF	0.5710	0.1706	0.1677	0.3187
	0.00	0.00	0.00	0.00
	310	301	314	314
ZNETER1	0.0696	0.2663	0.0106	0.4995
	0.23	0.00	0.85	0.00
	301	292	305	305
ZMANALID	-0.0618	-0.2315	0.1314	-0.0723
	0.29	0.00	0.02	0.21
	298	301	301	301
ZCOMPLY1	0.0567	0.0962	0.3019	0.2927
	0.33	0.10	0.00	0.00
	302	293	306	306
ZIPPCO3	0.0229	0.0515	0.2390	0.1914
	0.69	0.38	0.00	0.00
	299	297	299	299
ZCON110	0.1485	0.0567	0.1246	0.1214
	0.01	0.33	0.03	0.03
	310	298	310	310
ZLNCH110	1.0000	0.2250	0.0319	0.2291
	0.00	0.00	0.58	0.00
	310	298	310	310
ZATC3RAT	0.2250	1.0000	-0.1172	0.6974
	0.00	0.00	0.04	0.00
	298	301	301	301
ZMOP123	0.0319	-0.1172	1.0000	-0.0700
	0.58	0.04	0.00	0.22
	310	301	314	314
ZTLL123	0.2291	0.6974	-0.0700	1.0000
	0.00	0.00	0.22	0.00
	310	301	314	314

Table A.4

Reliability Coefficients

Variable	Alpha
Battlefield survival	0.801
Tactical proficiency	0.605
Technical proficiency	0.737
Combined asset damage: scenarios 1,2,3	0.503
Combined hostile aircraft killed (IAW tactics): scenarios 1,2,3	0.714
Combined missile conservation: Scenarios 1,2,3	0.556

Table A.5

Regression Results

DEPENDENT VARIABLE	R-SQUARE	INTERCEPT	T	AFQT	T	OPERMON	T	UNITMEM	T	TRAINDAY	T	LOCPRG	T	TDAMAINT	T
ZDAMAGE1	.05	-0.708	-3.31	0.009	2.92	0.006	0.84	0.141	0.93	0.004	1.16	-0.020	0.14	.	
ZDAMAGE2	.12	-0.998	-4.90	0.012	4.43	0.017	2.47	0.065	0.45	0.003	0.80	0.113	0.84	.	
ZDAMAGE3	.12	-0.829	-4.02	0.011	4.08	0.017	2.46	-0.178	-1.21	0.008	2.39	0.119	0.88	.	
ZDAMAGE4	.06	-0.219	-1.01	0.003	0.98	0.008	1.04	-0.269	-1.74	-0.001	-0.17	0.396	2.74	0.445	1.66
ZDAM_A2	.06	-0.533	-2.54	0.005	1.79	0.014	1.99	0.060	0.40	0.003	0.94	0.132	0.95	.	
ZDAM_B2	.09	-0.985	-4.77	0.013	4.75	0.012	1.74	0.043	0.29	0.001	0.33	0.051	0.38	.	
ZDAM_A3	.06	-0.505	-2.37	0.006	1.97	0.003	0.42	-0.099	-0.65	0.008	2.30	0.290	2.07	.	
ZDAM_D3	.12	-0.874	-4.22	0.011	3.86	0.018	2.58	-0.050	-0.34	0.005	1.53	0.150	1.10	.	
ZDAM_E3	.07	-0.534	-2.51	0.009	3.01	0.014	2.01	-0.202	-1.33	0.005	1.63	-0.048	-0.35	.	
ZDAM_A4	.03	0.066	0.30	0.001	0.29	0.000	0.06	-0.358	-2.27	-0.001	-0.34	0.337	2.30	0.020	0.07
ZDAM_B4	.04	0.024	0.11	-0.001	-0.35	-0.005	-0.64	-0.173	-1.11	0.002	0.53	0.382	2.62	0.342	1.26
ZDAM_C4	.06	-0.392	-1.82	0.005	1.57	0.013	1.79	-0.091	-0.59	-0.004	-1.08	0.222	1.54	0.584	2.18
ZDAM_D4	.05	-0.341	-1.57	0.004	1.41	0.003	0.43	-0.181	-1.16	0.002	0.54	0.362	2.49	0.349	1.30
ZDAM_E4	.04	0.054	0.25	-0.000	-0.12	0.014	1.96	-0.305	-1.92	-0.002	-0.59	0.236	1.62	0.336	1.28
ZDIFB2A2	.02	0.452	2.11	-0.008	-2.62	-0.000	-0.01	0.005	0.04	0.001	0.39	0.051	0.36	.	
ZDIFD3A3	.03	0.390	1.80	-0.005	-1.78	-0.014	-1.89	-0.032	-0.21	0.001	0.39	0.088	0.62	.	
ZDIFE3A3	.04	0.284	1.32	-0.006	-2.04	-0.013	-1.80	0.155	1.00	-0.002	-0.45	0.204	1.44	.	
ZDIFD3E3	.02	-0.019	-0.09	0.002	0.80	0.004	0.48	-0.174	-1.11	0.002	0.70	-0.141	-0.98	.	
ZHOKILL1	.01	0.148	0.69	-0.000	-0.15	0.001	0.17	-0.168	-1.07	0.002	0.73	-0.084	-0.59	.	
ZHOKILL2	.11	-0.959	-4.67	0.010	3.52	0.011	1.66	0.207	1.41	0.002	0.63	0.248	1.86	.	
ZHOKILL3	.11	-0.856	-4.09	0.013	4.59	0.013	1.88	-0.218	-1.46	0.006	1.73	0.128	0.94	.	
ZHOKILL4	.07	-0.540	-2.49	0.007	2.38	0.013	1.86	-0.198	-1.28	-0.002	-0.45	0.373	2.60	0.233	0.90
ZHIAW1	.12	-0.889	-4.38	0.008	3.01	0.010	1.50	0.309	2.09	0.008	2.37	0.005	0.04	.	
ZHIAW2	.10	-0.964	-4.66	0.009	3.16	0.005	0.68	0.580	3.92	-0.003	-0.85	-0.028	-0.21	.	
ZHIAW3	.13	-1.060	-5.13	0.012	4.29	0.010	1.46	0.260	1.76	0.007	2.27	-0.044	-0.33	.	
ZHIAW4	.07	-0.776	-3.58	0.009	2.96	0.009	1.29	0.443	2.85	-0.001	-0.25	-0.337	-2.35	0.044	0.17
ZFRKILL1	.03	-0.083	-0.39	0.003	1.15	0.007	1.03	-0.416	-2.70	0.003	0.97	0.203	1.44	.	
ZFRKILL2	.02	-0.281	-1.31	0.003	1.08	0.005	0.66	-0.040	-0.26	-0.000	-0.05	0.203	1.43	.	
ZFRKILL3	.02	0.050	0.23	-0.001	-0.44	-0.017	-2.31	0.056	0.36	0.002	0.53	0.186	1.29	.	

Table A.5—continued

DEPENDENT VARIABLE	R-SQUARE	INTERCEPT	T	AFQT	T	OPERMON	T	UNITMEM	T	TRAINDAY	T	LOCPRG	T	TDAMAINT	T
ZFRKILL4	.02	-0.184	-0.83	0.003	1.14	-0.010	-1.38	0.087	0.55	0.003	0.87	-0.194	-1.32	0.202	0.74
ZIPERCOR	.43	-1.397	-8.60	0.014	6.40	0.040	7.25	0.057	0.49	0.008	3.22	0.357	3.33	.	
ZTPERCOR	.37	-0.858	-4.40	0.009	3.06	0.059	8.56	.	.	0.002	0.55	-0.122	-1.01	.	
ZMSLCON1	.07	-0.753	-3.58	0.008	2.70	0.007	1.01	0.239	1.56	0.005	1.63	-0.015	-0.11	.	
ZMSLCON2	.06	-0.626	-2.93	0.006	2.00	0.003	0.36	0.512	3.34	-0.007	-2.02	-0.129	-0.93	.	
ZMSLCON3	.05	-0.699	-3.25	0.007	2.34	0.001	0.14	0.431	2.76	0.002	0.76	-0.168	-1.18	.	
ZMSLCON4	.03	-0.128	-0.57	0.000	0.13	-0.002	-0.28	0.392	2.44	-0.000	-0.01	-0.409	-2.78	0.178	0.67
ZNETER1	.09	-0.584	-2.80	0.004	1.57	0.017	2.35	0.183	1.22	0.002	0.74	0.134	0.97	.	
ZMANALID	.06	-0.337	-1.58	0.007	2.32	0.012	1.62	-0.109	-0.71	0.004	1.21	-0.316	-2.24	.	
ZCOMPLY1	.13	-0.742	-3.64	0.006	2.05	0.015	2.15	0.286	1.96	0.007	2.21	0.066	0.49	.	
ZCOMPLY4	.09	-0.597	-2.72	0.004	1.35	0.010	1.42	0.191	1.22	0.003	0.91	0.314	2.15	-0.186	-0.68
ZIFFCO3	.22	-0.995	-5.09	0.009	3.50	0.034	5.20	0.212	1.51	0.001	0.45	0.103	0.80	.	
ZHFR4	.08	-0.480	-1.80	0.005	1.39	0.004	0.44	-0.122	-0.64	0.003	0.61	0.553	3.11	-0.524	-1.59
ZAUT1	.05	-0.257	-1.03	0.003	1.01	0.011	1.26	-0.301	-1.69	0.003	0.84	0.384	2.34	.	
ZFRND3	.01	-0.195	-0.89	0.003	0.85	0.006	0.75	-0.043	-0.27	0.002	0.66	0.021	0.14	.	
ZSHFR4	.20	-0.947	-4.70	0.008	2.73	0.005	0.70	0.270	1.87	-0.000	-0.03	0.677	5.03	-0.317	-1.27
ZSCFR4	.15	-0.639	-3.09	0.003	1.13	0.004	0.62	0.248	1.67	0.001	0.18	0.562	4.07	0.144	0.56
ZCONA1	.05	-0.536	-2.15	0.004	1.31	0.009	1.08	0.163	0.91	-0.001	-0.18	0.219	1.33	.	
ZCONA2	.04	-0.593	-2.77	0.008	2.67	0.004	0.55	-0.071	-0.46	0.004	1.08	0.209	1.48	.	
ZCONA3	.02	0.298	1.36	-0.003	-0.90	0.007	0.92	-0.311	-1.98	0.004	1.19	0.037	0.26	.	
ZCONB1	.22	-1.114	-4.92	0.011	3.43	0.017	2.19	0.144	0.89	0.002	0.64	0.534	3.58	.	
ZCONB2	.03	-0.419	-1.94	0.005	1.83	0.007	0.99	-0.057	-0.37	0.001	0.33	0.178	1.25	.	
ZCONB3	.03	0.042	0.20	-0.002	-0.51	0.013	1.72	-0.127	-0.81	-0.002	-0.56	0.236	1.64	.	
ZLNCHA1	.10	-0.862	-3.57	0.009	2.62	0.011	1.29	0.173	1.00	0.002	0.54	0.286	1.80	.	
ZLNCHA2	.03	-0.306	-1.41	0.005	1.78	-0.002	-0.24	-0.084	-0.55	-0.005	-1.33	0.196	1.38	.	
ZLNCHB1	.14	-1.023	-4.30	0.011	3.42	0.006	0.72	0.095	0.56	0.005	1.31	0.413	2.64	.	
ZLNCHB2	.02	-0.403	-1.86	0.006	2.15	-0.007	-0.91	0.039	0.25	-0.002	-0.46	0.047	0.33	.	
ZLNCH3	.04	-0.227	-1.05	0.005	1.86	-0.010	-1.36	-0.125	-0.80	0.007	1.96	-0.136	-0.95	.	
ZCON80	.02	-0.275	-1.28	0.004	1.30	0.008	1.15	-0.042	-0.28	0.003	0.94	-0.072	-0.51	.	
ZCON110	.05	-0.521	-2.47	0.005	1.88	0.016	2.31	0.075	0.50	-0.000	-0.04	0.113	0.81	.	
ZLNCH80	.04	-0.629	-2.95	0.010	3.37	0.001	0.07	-0.027	-0.18	0.001	0.36	0.024	0.17	.	
ZLNCH110	.05	-0.734	-3.47	0.011	3.78	-0.003	-0.49	0.002	0.01	0.004	1.18	0.008	0.06	.	

Table A.5—continued

DEPENDENT VARIABLE	R-SQUARE	INTERCEPT	T	AFQT	T	OPERMON	T	UNITMEM	T	TRAINDAY	T	LOCPRG	T	TDAMAINT	T
ZMOF1RAT	.02	-0.273	-1.27	0.003	0.99	0.013	1.73	-0.011	-0.07	0.002	0.53	0.010	0.07	.	
ZMOF2RAT	.04	-0.613	-2.88	0.008	2.93	0.009	1.23	0.072	0.47	-0.005	-1.53	0.050	0.36	.	
ZMOF3RAT	.12	-1.063	-5.15	0.015	5.28	0.009	1.27	-0.062	-0.42	0.006	1.91	0.114	0.84	.	
ZMOF1,2,3	.07	-0.805	-3.98	0.011	3.85	0.013	1.93	0.063	0.43	0.001	0.27	0.031	0.23		
ZMOF4RAT	.03	-0.115	-0.52	0.003	0.91	0.004	0.58	-0.266	-1.69	-0.003	-0.87	0.287	1.95	0.262	0.96
ZTLL1RAT	.07	-0.758	-3.60	0.007	2.49	0.006	0.84	0.387	2.56	0.004	1.34	-0.110	-0.79	.	
ZTLL2RAT	.06	-0.589	-2.80	0.005	1.61	-0.007	-0.99	0.591	3.92	0.002	0.46	-0.221	-1.60	.	
ZTLL3RAT	.06	-0.475	-2.22	0.002	0.79	0.003	0.37	0.557	3.62	0.000	0.07	-0.187	-1.33	.	
ZTLL1,2,3	.07	-0.759	-3.60	0.007	2.49	0.006	0.84	0.387	2.56	0.004	1.34	-0.110	-0.79		
ZTLL4RAT	.04	-0.365	-1.67	0.003	0.93	-0.001	-0.17	0.475	3.03	-0.001	-0.19	-0.313	-2.15	-0.017	-0.06
ZFLT1RAT	.02	-0.225	-1.04	0.001	0.21	-0.007	-1.01	0.240	1.55	0.006	1.64	0.016	0.12	.	
ZFLT2RAT	.03	-0.071	-0.33	-0.002	-0.63	0.000	0.00	0.410	2.67	0.001	0.34	-0.270	-1.92	.	
ZATC3RAT	.05	-0.362	-1.68	0.001	0.36	-0.003	-0.38	0.518	3.36	0.002	0.58	-0.166	-1.17	.	
ZATC4RAT	.04	-0.279	-1.28	0.003	0.91	-0.001	-0.17	0.387	2.48	0.002	0.62	-0.422	-2.90	-0.122	-0.45
ZSLO1RAT	.02	-0.069	-0.32	0.003	0.87	0.003	0.37	-0.028	-0.18	0.001	0.27	-0.253	-1.78	.	
ZSLO2RAT	.01	0.349	1.62	-0.005	-1.55	0.001	0.11	0.029	0.19	-0.002	-0.72	-0.148	-1.04	.	
ZSLO3RAT	.09	-0.129	-0.62	0.005	1.63	-0.025	-3.58	0.043	0.29	0.008	2.54	-0.332	-2.41	.	
ZSLO4RAT	.03	-0.069	-0.31	0.003	0.95	0.001	0.08	-0.029	-0.19	0.002	0.68	-0.240	-1.64	-0.436	-1.61
ZSPC1RAT	.01	0.112	0.51	-0.002	-0.82	0.009	1.24	0.009	0.06	0.000	0.10	-0.048	-0.33	.	
ZSPC3RAT	.02	-0.138	-0.63	0.001	0.49	-0.012	-1.69	-0.063	-0.41	0.002	0.70	0.340	2.37	.	
ZSPC4RAT	.04	0.516	2.37	-0.004	-1.41	-0.001	-0.10	-0.468	-3.00	-0.001	-0.41	0.233	1.60	0.017	0.06
PTACPRO1	.15	-1.069	-5.36	0.011	4.12	0.012	1.72	0.292	2.01	0.008	2.50	-0.003	-0.03	.	
PTACPRO2	.12	-1.109	-5.46	0.011	4.09	0.010	1.41	0.504	3.46	-0.002	-0.53	-0.004	-0.03	.	
PTACPRO3	.15	-1.110	-5.45	0.013	4.76	0.012	1.79	0.184	1.26	0.008	2.47	-0.022	-0.17	.	
PTACPRO4	.07	-0.805	-3.72	0.010	3.28	0.012	1.68	0.288	1.86	0.000	0.04	-0.236	-1.65	0.246	0.96
PTACPRO	.19	-1.323	-6.83	0.014	5.44	0.015	2.22	0.401	2.89	0.006	1.87	-0.029	-0.22	.	
STACPRO1	.13	-0.839	-4.12	0.008	2.71	0.019	2.76	0.290	1.99	0.005	1.43	0.007	0.05	.	
STACPRO2	.07	-0.861	-4.11	0.009	3.29	0.001	0.18	0.473	3.15	-0.003	-0.79	-0.122	-0.89	.	
STACPRO3	.11	-0.971	-4.67	0.011	3.89	0.009	1.29	0.344	2.31	0.006	1.80	-0.203	-1.48	.	
STACPRO4	.08	-0.866	-3.92	0.010	3.38	0.006	0.81	0.393	2.52	-0.007	-1.93	-0.112	-0.78	0.417	1.62
STACPRO	.14	-1.100	-5.51	0.011	4.20	0.014	2.02	0.448	3.13	0.004	1.31	-0.147	-1.11		

Table A.5—continued

DEPENDENT VARIABLE	R-SQUARE	INTERCEPT	T	AFQT	T	OPERMON	T	UNITMEM	T	TRAINDAY	T	LOCPRG	T	TDAMAINT	T
TEKPROF1	.33	-1.338	-7.60	0.012	5.10	0.028	4.78	0.298	2.36	0.006	2.20	0.318	2.74	.	
TEKPROF2	.13	-1.035	-5.16	0.013	4.77	0.014	2.14	-0.042	-0.29	0.003	0.85	0.305	2.31	.	
TEKPROF3	.21	-0.932	-4.88	0.010	3.88	0.031	4.85	-0.053	-0.39	0.006	1.85	0.227	1.81	.	
TEKPROF4	.34	-1.177	-6.69	0.010	4.15	0.024	4.12	0.142	1.13	0.006	2.20	0.626	5.33	-0.160	-0.74
TEKPROF	.22	-1.223	-6.46	0.014	5.30	0.024	3.80	0.057	0.42	0.004	1.33	0.326	2.61	.	
DAMAGE1	.05	2.054	9.92	-0.008	-2.92	-0.006	-0.84	-0.137	-0.93	-0.004	-1.16	0.020	0.14	.	
DAMAGE2	.12	6.181	16.93	-0.022	-4.43	-0.030	-2.47	-0.116	-0.45	-0.005	-0.80	-0.203	-0.84	.	
DAMAGE3	.12	7.846	18.61	-0.023	-4.08	-0.035	-2.46	0.365	1.21	-0.016	-2.39	-0.243	-0.88	.	
DAMAGE4	.06	15.843	18.50	-0.011	-0.98	-0.030	-1.04	1.064	1.74	0.002	0.17	-1.566	-2.74	-1.759	-1.66
DAMAGE	.18	16.047	22.23	-0.051	-5.22	-0.078	-3.20	-0.066	-0.13	-0.023	-2.05	-0.228	-0.48	.	
HIAW1	.12	5.359	8.00	0.028	3.01	0.034	1.50	1.020	2.09	0.025	2.37	0.016	0.04	.	
HIAW2	.10	13.434	16.93	0.034	3.16	0.018	0.68	2.224	3.92	-0.010	-0.85	-0.107	-0.21	.	
HIAW3	.13	16.048	11.75	0.079	4.29	0.066	1.46	1.721	1.76	0.048	2.27	-0.291	-0.33	.	
HIAW4	.07	7.365	7.18	0.041	2.96	0.043	1.29	2.094	2.85	-0.004	-0.25	-1.594	-2.35	0.206	0.17
HIAW	.17	34.433	15.10	0.150	4.84	0.115	1.49	5.020	3.07	0.063	1.77	-0.637	-0.42	.	
MSLCONS1	.07	5.051	10.53	-0.018	-2.70	-0.016	-1.01	-0.544	-1.56	-0.012	-1.63	0.035	0.11	.	
MSLCONS2	.06	2.166	20.26	-0.003	-2.00	-0.001	-0.36	-0.255	-3.34	0.003	2.02	0.064	0.93	.	
MSLCONS3	.05	2.708	16.91	-0.005	-2.34	-0.001	-0.14	-0.320	-2.76	-0.002	-0.76	0.125	1.18	.	
MSLCONS4	.03	6.962	5.19	-0.002	-0.13	0.012	0.28	-2.335	-2.44	0.000	0.01	2.435	2.78	-1.059	-0.67
MSLCONS	.06	2.635	20.28	-0.005	-2.80	-0.001	-0.32	-0.246	-2.63	-0.001	-0.68	0.069	0.80	.	
IPERCOR	.43	0.295	12.06	0.002	6.40	0.006	7.25	0.009	0.49	0.001	3.22	0.054	3.33	.	
TPERCOR	.37	0.368	9.84	0.002	3.06	0.011	8.56		.	0.000	0.55	-0.023	-1.01	.	
NETER1	.09	4.965	8.45	-0.013	-1.57	-0.047	-2.35	-0.515	-1.22	-0.007	-0.74	-0.376	-0.97	.	
MANUALID	.06	0.230	4.51	0.002	2.32	0.003	1.62	-0.026	-0.71	0.001	1.21	-0.075	-2.24	.	
COMPLY1	.13	0.345	4.62	0.002	2.05	0.005	2.15	0.105	1.96	0.003	2.21	0.024	0.49	.	
IFFCO3	.22	0.010	0.11	0.005	3.50	0.017	5.20	0.106	1.51	0.001	0.45	0.051	0.80	.	
MOF123	.07	0.248	18.35	-0.001	-3.85	-0.001	-1.93	-0.004	-0.43	-0.000	-0.27	-0.002	-0.23	.	
TLL123	.08	0.233	9.93	-0.001	-2.22	-0.000	-0.22	-0.065	-3.85	-0.000	-0.98	0.020	1.26	.	
ATCRATE3	.05	0.251	7.91	-0.000	-0.36	0.000	0.38	-0.076	-3.36	-0.000	-0.58	0.024	1.17	.	
CONSL110	.05	0.471	6.89	0.002	1.88	0.005	2.31	0.024	0.50	-0.000	-0.04	0.036	0.81	.	
LNCH110	.05	0.566	9.20	0.003	3.78	-0.001	-0.49	0.000	0.01	0.001	1.18	0.002	0.06	.	

Appendix B
ILLUSTRATIVE COST-BENEFIT ANALYSIS

Our results provide considerable evidence that AFQT score has a direct and significant impact on the outcomes of air battles. However, in a resource-constrained environment, decisionmakers must weigh these differences in outcomes against the additional cost of recruiting high quality soldiers. To explore such cost-benefit tradeoffs, we conducted a simple, illustrative analysis. Our analysis focused on Patriot missile usage and ECS damage.

RECRUITING COSTS

Previous research indicates that it costs more to recruit high quality soldiers than low quality soldiers (e.g., Polich, Dertouzos, and Press, 1986). It is difficult to estimate precisely the true additional cost. For illustrative purposes, we rely here on earlier RAND research results. In particular, earlier RAND work (circa 1985) reported that on a per-unit cost basis, the marginal cost of attracting an additional high quality recruit through advertising was about $6000. Similarly, the marginal cost was estimated at $5400 if staff increases (i.e., more recruiters) were used instead of advertising.[1] These figures contrast with the cost of recruiting a low quality soldier, which was estimated to be about $2000. Thus, the estimated marginal increase in cost for a high quality soldier in 1985 was approximately $4000. Taking inflation into account, we estimate that the 1990 amounts would be about $6800 for a high quality recruit and $2300 for a low quality recruit, a difference of $4500.[2]

MISSILE USAGE

Based on the regression coefficients produced in the missile usage analysis, we calculated the expected number of missiles required to kill ten hostile aircraft in accordance with tactics at the midpoint of each AFQT category. These numbers were presented in Figure 10. The analysis suggests that usage increases by about one missile per AFQT category for each ten tactically correct kills. For example, a category IIIB soldier would use approximately two more missiles than a category II soldier for ten kills, four more for 20 kills, and so forth, according to these results. The cost of each missile was estimated at $570,000.

We then combined the missile usage results across categories I to IIIA to determine the number for high quality soldiers (21.0), and for categories IIIB and IV to get the number for low quality soldiers (23.2). When the cost of the missiles is considered, the implication is that low quality soldiers would require $1.1 million in additional resources for *each ten* tactically correct kills. The higher resource expenditure by low quality soldiers greatly exceeds the extra cost of recruiting high quality soldiers, which is about $4500 per soldier. Moreover,

[1]These numbers could be higher if bonuses were used to entice potential recruits.

[2]These numbers were determined from deflators in the *International Financial Statistics, Yearbook 1989* (International Monetary Fund, 1989). The 1990 cost was calculated by using $6000 and $2000 as the 1985 base-year costs. Also, since the 1989 deflator was not available at the time of this writing, it was estimated at 113.3, which assumes a relative increase of 3.3 percent during 1989, the average increase over the last 5 years (1986–1990).

the regression results suggest that the additional training resources and operator experience required for low quality soldiers to achieve the same level of proficiency as high quality soldiers are substantial and, alternatively, that such resources could be applied to achieve even better performance among high quality soldiers.

ASSET DAMAGE

A similar analysis was undertaken for asset damage. Although such an analysis required more assumptions than did that for missile usage, the results appear to be generally similar. Using the numbers presented earlier in Figure 8, we estimated that asset damage increased by about one hit per 28 potential strikes for each AFQT category. This increase translates to a difference of about 0.83 hits per ten potential strikes when we combine results and compare category I through IIIA soldiers with category IIIB and IV soldiers. Given the wide variation in the nature of defended assets, it is difficult to derive an "average" cost for them, and similarly difficult to determine the number of enemy strikes required for their destruction. For this illustration, we used the cost of an ECS, $4,033,000, and assumed that two to three strikes would destroy the ECS (or another asset of comparable value). Using a three-strike figure, each hit would do about $1.3 million worth of damage. Given an expected difference of 0.83 hits, the cost of increased asset damage for low quality soldiers would be $1.1 million for each ten potential enemy strikes. Again, the marginal cost increase in recruiting high quality soldiers is more than offset by the savings in improved job performance.

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